CHALLENGING EPISTEMIC BIASES IN MUSICAL AI: A GUERRILLA APPROACH TO HUMAN-MACHINE COMPROVISATION BASED ON XENAKIS'S SKETCHES FOR *EVRYALI*

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ABSTRACT

The objective of this paper is to reflect on the affordances of sketches as interfaces for human and machine learning, by way of a case study based on Iannis Xenakis's *Evryali* (1973). First, I report on one-to-one mappings between the composer's original sketches and the symbolic notation intended for performance. Then, there is an outline of the sketches' deviations from the symbolic score and their potential to offer indispensable analytical insights for learning. The decoupling of sketch and score intensifies as performance multimodal data enters the framework of my analysis, allowing for the emergence of one-to-many mappings among those three distinct representation domains. This multiplicity of relations fuels the creation of gesture-controlled, augmented, and interactive tablatures, which are based on the sketches and incorporate graphic and multimodal elements to bypass conventional notation. Finally, I report on the use of tablatures as both preparation and performance tools in a human-machine comprovisation setting, involving a human trained to improvise on complex scores, an AI agent trained on a corpus of recordings, and a gesture-follower trained on the performance of sketches. As a postlude, the potential of one-to-many mappings for challenging established epistemic biases in musical AI is stressed. I capitalize on the unpredictability generated by the interplay between couplings and decouplings of different representation domains, affirming the transitory nature and inherent malleability of sketches.

1. XENAKIS AND GRAPHICS

Although the relationship of the architect, engineer, and composer Iannis Xenakis to graphic design might seem too intuitive to stress, some of his writings offer a more convoluted image.

The first element to point out is that sketches facilitated Xenakis's control over global formal properties that are not readily accessible in the symbolic notation of serial linear polyphony. His proposition of "a world of sound masses, vast groups of sound events, clouds, and galaxies governed by new characteristics such as density, degree of order, and rate of change" [1, p. 182] wouldn't have been possible without both probability theory and the visual means to implement it. The sketch is integral for the application of stochastic and probabilistic laws that were hitherto impossible.

Second, Xenakis dissociates the term "sketch" from its graphic implementation when he, for example, refers to symbolic music as a "logical and algebraic sketch of musical composition." [1, p. 155] This conceptual dissociation becomes clearer as Xenakis warns against the "fetish of the graphic symbol", whereby "the music is judged according to the beauty of the drawing." He does so in favour of a functional or algorithmic perception: "[...] graphical writing, whether it be symbolic, as in traditional notation, geometric, or numerical, should be no more than an image that is as faithful as possible to all the instructions the composer gives to the orchestra or to the machine." [1, p. 180]

A final word should be uttered in relation to Xenakis's theory of musical time and the distinction between *temporal*, *inside time* and *outside of time* materials [2]. The distinction indicates a dialectic between the graphic representation of instructions and the clash they generate between lived experience and fixed architectures on a "blank blackboard of time, on which symbols and relationships, architectures and abstract organisms are inscribed." [1, p. 192]. This dialectic of lived and abstract time might later prove indispensable for the leap from a score reproduction mode characteristic of high modernism [3] to a multimodal comprovisation mode based on sketches, or the leap from one-to-one towards one-to-many mappings.

In what follows, I opt for a bottom-up approach. I deterritorialize the idea of a sketch from the inside, showing how even the simplest mappings can produce a variable matrix of performance possibilities, before being further repurposed towards other goals, such as gesture following based on machine learning and Human-AI coadaptation based on audio and MIDI recordings. Artistic "guerrilla" practice complements a strict methodology of mappings and functionalities, allowing for a vital counterpart to Markov Models and Factor Oracles, the human(-in-the-loop)[1] [4] as “ghost in the machine” (after Gilbert Ryle).

2. ONE-TO-ONE MAPPINGS

2.1. Simple

A reproduction model of the musical score assumes a tight coupling between symbolic elements and their sketch counterparts. This will also be my own departure point, albeit with the intention of discovering decouplings, which render sketches indispensable.

Figure 1 presents a case of obvious one-to-one mapping of pitch and rhythm information. Bar 1 is annotated in red to show pitch correspondences between sketch and score, and bar 3 in blue for rhythm information respectively. One cell per semitone on the vertical axis and one cell per 16th note on the horizontal axis of the sketch allow for an accurate representation of pitches, bar lines, and attacks’ positioning (or composite rhythm), but crucially not the duration of individual attacks. Indicating duration has required an extra annotation layer of blue lines for the 16th and orange lines for the 8th notes (bar 3).

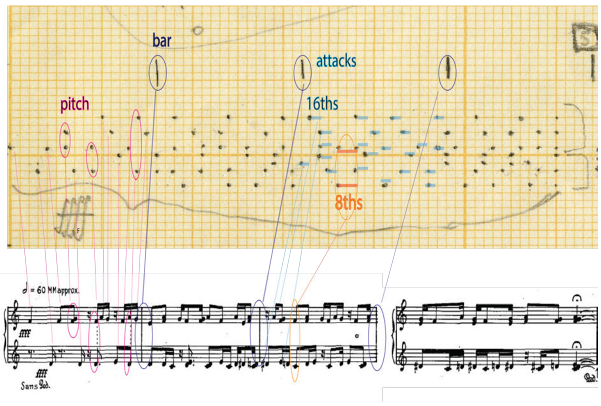

Figure 1. One-to-one mappings in the pitch and rhythm domains. Sketch reproduction of *Evryali*, bars 1–4, with kind permission by the Xenakis Archive – Mâkhi Xenakis

2.2. Complex

Figure 2 presents a more nuanced case, whereby pitch and rhythm information is complemented by information on texture and form that is not afforded by the symbolic score. First, a notion of “isodynamic lines polyphony” features in the sketch as lines connecting pitches bearing the same dynamic (texture B in pink frame). This texture is complemented by a distinct texture based on repeated notes (C in purple ellipse), which appears to be an embellishment rather than an interruption of the general form (D in green ellipse). Both features, the polyphony of dynamic lines and the hierarchy of the two textures, are hard if not impossible to discern in the pointillistic symbolic score. In that sense, the symbolic score presents lower affordances for performance, whereas the sketch presents higher-order information decoupled from the performers’ score.

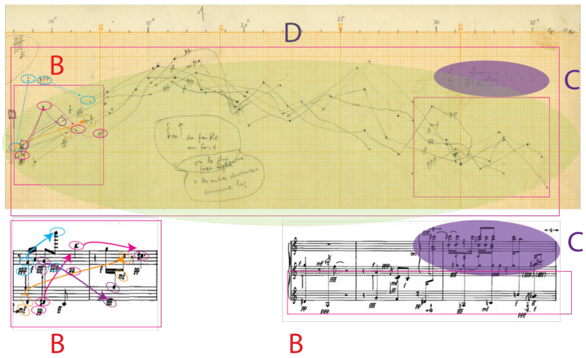

Figure 2. One-to-one mappings that reveal textures and formal properties not readily accessible in the symbolic score. Sketch reproduction of *Evryali*, bars 5–18, with kind permission by the Xenakis Archive – Mâkhi Xenakis

2.3. Global

In Figure 3, the complete annotated *Evryali* sketches have been assembled into a single representation, which provides a rapid understanding of the work’s global form. This understanding is based on meticulous analysis of texture, as well as on the difficulty and occasionally impossibility of realizing the textures in performance, as a measure of the work’s complexity. Different colours indicate different textural types. Each of the original composer’s sketches contains two lines. Each textural frame is indexed through a verbal description, its correspondence to the published score by *Editions Salabert* (page and bar numbers) and the track number, indicating reference recordings.

According to this analysis, the articulation of the piece’s form is governed by the following parameters:

a.) Alternation between blocks of points and linear arborescences [5] of varying complexity. For example: First theme texture (as in Figure 1) versus second theme texture, as in Figure 2 (sketch no. 1, line no. 1, light blue versus pink frames in Figure 3).

b.) Alternation between possible and impossible textures in terms of performability. Impossible passages are indicated with orange filters. For example, sketch 3, line no. 1, yellow versus orange frames.

c.) Alternation between simple and superimposed textures (for superimposed textures, refer indicatively to sketch no. 4, line no. 2).

d.) Silences (green frames, indicatively sketch no. 2, line no. 2).

[1] “When problems have not yet been formalized, they can still be characterized by a model of computation that includes human computation. The computational burden of a problem is split between a computer and a human: one part is solved by a computer and the other part solved by a human. This formalization is referred to as the human-assisted Turing machine.”

Figure 3. Complete textural and global form annotation and analysis of the sketches of *Evryali* with kind permission by the Xenakis Archive – Mâkhi Xenakis

3. ONE-TO-MANY MAPPINGS

3.1. Embodied Learning

The notion of embodied learning encapsulates a central hypothesis: that gesture/movement can be a form of processing textual complexity, including both quantitative and qualitative characteristics. This processing both reduces the dimensionality of symbolic information by folding it into higher-order co-articulation units [6, p. 2][2] and multiplies it through the production of one-to-many mappings between lower affordances, higher-order parameters or descriptors, and different hierarchical layers of embodiment.

3.2. Multimodal Data and Sketches

As is the case with symbolic scores, sketches are highly decoupled from the performers' embodied view of the work. To demonstrate this, I conducted an analysis of a performance of the "cadenza expansion" section (sketch no. 4, line no. 2 in Figure 3) using multimodal data, including Inertial Measurement Units (IMU) and MIDI, visualized, annotated and synchronized through the MuBu (Multiple Buffer) toolbox in Max/MSP. The simple triangular form of the sketch as an expansion in pitch and time space is counterbalanced by the complex hand choreography necessary to perform it. In Figure 4, this choreography is defined and visually communicated through markers indicating the position in time of hand displacements as measured by the gyroscopic information of the multimodal data. Video 1 shows an audiovisual recording of the passage synchronized to the multimodal data and subsequently an interactive demo clarifying how markers indicate displacements. The hand displacements define PADR envelopes for the pianist's gesture, P standing for zones of gesture preparation, A for zones of attacks without hand displacements, D for zones of displacements and R for the release gesture of the pianist.

The rate or density of displacements is here considered as a robust measure of complexity, which can function in relation to the ongoing research for developing complexity measures or indexes in music notation [7]. The relation between difficulty and notational complexity remains convoluted and requires further investigation.

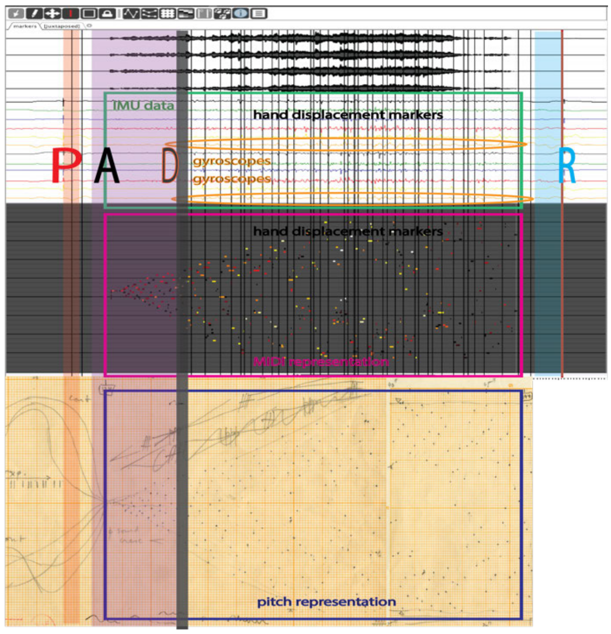

Figure 4. Comparison of a Xenakis sketch (bottom panel) with multimodal performance data including MIDI (middle panel) and IMU acceleration data (top panel). The gyroscopic information defines patterns of hand displacements that are used to define envelopes of gesture preparation (P), attack (A), displacement (D) and release (R). Sketch of *Evryali*, p.19, reproduced with kind permission by the Xenakis Archive – Mâkhi Xenakis

A good measure of the merits of Figure 4 in terms of direct perception is the citation of an annotated score of the same, as in Figure 5. In this traditional form of annotation, each displacement unit corresponds to a hand-drawn

[2] "Coarticulation means the subsumption of otherwise distinct actions and sounds into more superordinate actions and sounds, entailing a contextual smearing of otherwise distinct actions and sounds, e.g. rapid playing of scales and arpeggios on the piano will necessitate finger movements included in superordinate action trajectories of the wrists, elbows, shoulders, and even whole torso, as well as entail a contextual smearing of the singular tones into superordinate contours of the scales or arpeggios. […] One essential element of coarticulation is that it concerns both the production and the perception of sound, hence that it clearly unites sound and action into units, into what we prefer to call sound-action chunks in music".

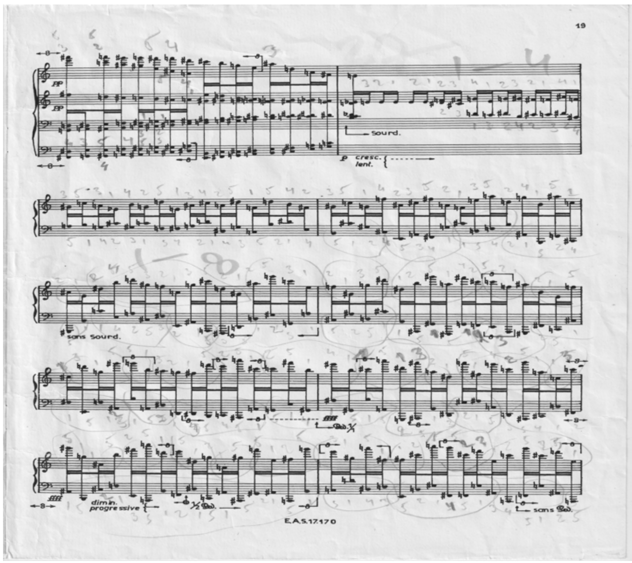

Figure 5. Published score annotation by the author for *Evryali*, p. 19, reproduced with kind permission of *Editions Salabert*

circle, indicating a hand-grasp of pitch information. While this sort of cumulative implicit knowledge remains indispensable for the performer's learning process, the neat combination of local and global aspects in Figure 4 makes explicit to the non-performer information that is absent from either the sketch or the score alone.

3.3. Augmented Interactive Tablatures

The stark contrast between local embodied detail and global formal properties in Xenakis demands an augmented interactive representation functioning as an interface for learning and performance, beyond both the massive details of the symbolic notation and the perception of form through sketches.

I employed the INScore to create an augmented interactive tablature based on a rendition of the complete *Evryali* sketches as a single timeline. Check Figure 6 for a sample of INScore's scripting language, an extended textual version of Open Sound Control messages, for the following string: /ITL/scene/score set img "evryali_sketches_timeline_black-bg.png;". This string places the representation of Figure 7 in the INScore scene.

As a first step, the INScore formalism was used to create mappings between graphic space expressed in pixels and musical time expressed in traditional time signatures ("([54, 1267[[538, 1371[) ([0/4, 1/4[)" etc). Based on this mapping, which can be variable, I synchronized elements such as cursors (/ITL/scene/sync cursor score;) and graphic signals rendering already recorded gestures (/ITL/scene/sync cursor score;).

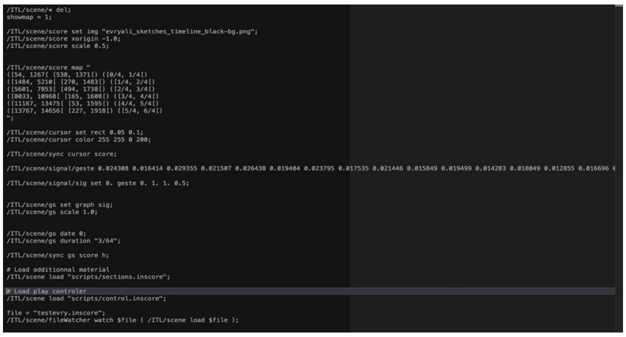

Figure 6. INScore script for creating an augmented and interactive representation based on Xenakis's sketches

As a second step, I experimented with different mappings and views of the score, often even with multiple renderings of the sketch simultaneously, including linear and non-linear readings. Non-linear readings allow for a navigation of the score that reflects analytical insights or embodied learning. One could, for example, group similar textures or similar choreographies, by creating respective mappings.

Figure 7 shows a rendering of the textures already presented in Figures 1 and 2, which includes a linear (upper line) and a non-linear (bottom line) reading of the sketch. Video 2 presents a screen recording without sound of a) a non-linear close-up view of the upper sketch in Figure 7 and b) the simultaneous sending of clock messages from Max/MSP to an overview of these two representations, visualized via a respective cursor and signal.

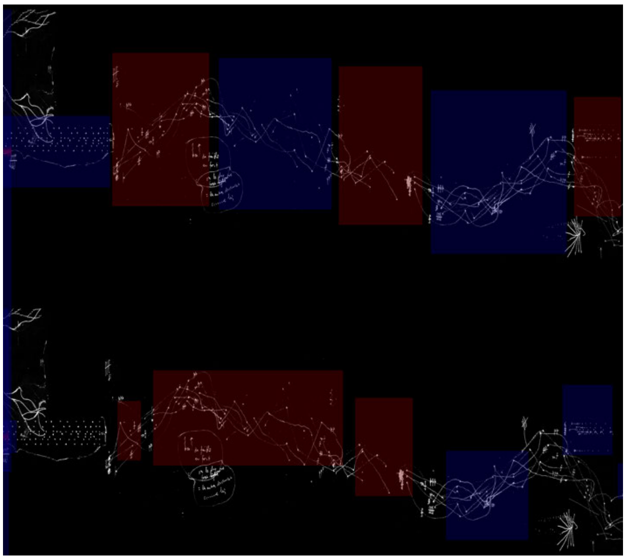

Figure 7. Graphic result of two different mappings of the *Evryali* sketches that correspond to bars 1–18. The upper mapping is linear, thus the alternation of blue and red regions defines the mapping. The lower mapping is non-linear, connecting any regions in the sketch, thus the succession of monochromatic regions.

4. FROM SCORE REPRODUCTION TO STRUCTURED COMPROVISATION

Having already learned the piece in meticulous detail, the augmented interactive tablature with variable representations and mappings operated as a platform for initial experimentation with navigating similar textures, but also harmonic and melodic elements of the original. At this stage, I simply followed the mobile elements of the tablature along predefined paths.

In what follows, different ways of using the sketch-based augmented multimodal tablature for structured comprovisation are explored. First, I explore ways of training the tablature to follow the performers' gestures and applications in solo comprovisation. Then, I explore a duo comprovisation involving the AI agent SOMAX2 controlled by another human performer and the trained interactive tablature.

4.1. Training the Tablature: Motion Follower

By virtue of a syntax of movement and machine learning techniques, the multilayered tablature can be trained to follow the performer in variations of the initial performance. This system is based on a probabilistic motion-following methodology employing Hidden Markov Models [8] and on the PADR envelopes demonstrated in 3.2. The crucial element, that allows for the motion-following to be reflected in the notation and thus become score-following, is that both the gesture and the notation share the same basic segmentation.

The process involves a *recording phase* and a *following phase*. In the recording phase, the user follows any mobile element of the INScore, which is set to move at a desired speed as in Video 2, like a classic metronome would do. The musical sketch has already been graphically segmented and assigned a duration according to the INScore space-time formalism (explicit mapping). In this phase, the motion follower "learns", so to speak, the mapping from the performer's gesture captured by R-IoT IMUs (implicit mapping), while s/he follows the mapping of the INScore (explicit mapping). In the next phase defined as "following", the performer can pursue highly varied performances, ranging from heterophonic re-interpretations of the original to the introduction of a completely novel material that shares the same gestural segmentation. This time, it is not the performer that follows the system, but rather the system that follows the performer, given that the segmentation is correct and common in all these varied performances. Thus, the performer may control the mobile elements of the INScore tablature. The feedback of the follower has been extended to score compound representations. The gesture-following has been turned into score-following.

In Figure 8 the grey signal represents the implicit mapping gesture that the augmented multimodal tablature "learns" along the explicit mapping of Figure 7 in the recording phase. The green signal represents the new incoming signal that controls the tablature in the following phase, the signal that the tablature follows during variations of the initial performance.

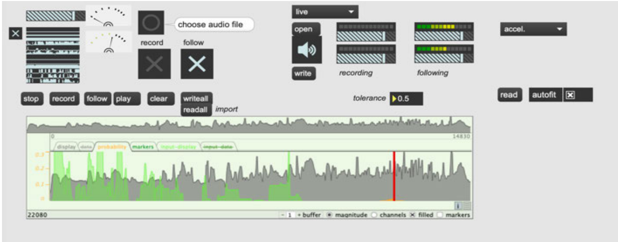

Figure 8. The green signal represents a new gesture that is probabilistically compared to the already recorded grey signal, allowing for the following of the performance by the system according to a threshold of tolerance

4.2. Training an AI Agent for Comprovisation: SOMAX2

In the last phase, I combined the motion following sketch-based tablature with a corpus of *Evryali* audio recordings used as training material for SOMAX2, which was trained and controlled live by Mikhail Malt. According to Malt, SOMAX2 is a multi-agent interactive system performing live machine comprovisation with musicians, based on machine-listening, machine-learning, and generative units. The actual version [9] is a recent development and algorithms' improvement from the former SOMAX version. Agents provide stylistically coherent improvisations based on learned musical knowledge while continuously listening to and adapting to input from musicians or other agents in real time. The system is trained on any musical materials chosen by the user, effectively constructing a generative model (called a corpus), from which it draws its musical knowledge and improvisation skills. Corpora, inputs and outputs can be MIDI as well as audio, and inputs can be live or streamed from MIDI or audio files. SOMAX2 is one of the improvisation systems descending from the Omax software [10], presented here in a totally new implementation. As such it shares with its siblings, the general loop [listen/learn/model/generate], using some form of statistical modeling that ends up in creating a highly organized memory structure from which it can navigate into new musical organizations, while keeping style coherence, rather than generating unheard sounds as other ML systems do.

Figure 9. Central window of SOMAX2 featuring the segmentation of an audio file containing a recording of *Evryali* (right side in green)

4.3. Improvising with the Tablature and SOMAX2

The open-ended nature of the resulting system allowed us to experiment with different kinds of interaction and materials in a setting of structured comprovisation based on Xenakis's *Evryali* sketches. Capitalizing on the *chroma* affinities between Xenakis's complete piano works, as well as music by Ravel and Janáček, we were able to construct composite corpora including harmonically similar language. In Videos 3,4,5 we present three different instances.

In the first instance (Video 3), the comprovisation between the human pianist (the author) and the AI agent controlled by Mikhail Malt is based exclusively on material by *Evryali,* featuring several degrees of distancing (same, similar and alien material) of the human pianist from the original material used to train SOMAX2. The complete performance is documented here.

In the second instance (Video 4), the pianist performer is gesturally controlling a recording from Xenakis's *Mists* (1980), first with air gestures and then with new material on the piano. The new material is shaped by the performer according to an *Evryali* tablature (Figure 10, pink frame). The supervp.scrub~ object (advanced phase vocoder position controlled player module) allows resynthesized audio output from the follower to be sent to SOMAX2, still controlled by Mikhail Malt, improvising on the time-stretching, pitch transposition, spectral envelope transformations of the original recording at times when the systems fail to follow.

In the third instance (Video 5), the piano performer is similarly performing air gestures and a heterophonic duet based on audio material from "Oiseaux Tristes" by Maurice Ravel, his movements controlling the *Evryali* tablature projected in the right-hand corner of the video (Figure 11). The SOMAX2 controlled by Mikhail Malt responds as above (instance 2).

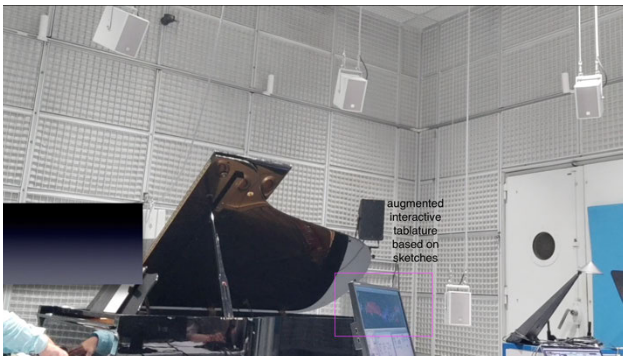

Figure 10. Snapshot from Video 4, annotated. Augmented interactive tablature based on *Evryali* sketches is used as a graphic score for a co-adaptive improvisation of a human performer, Pavlos Antoniadis, with SOMAX2 controlled by Mikhail Malt, including air gestures and piano based on another piece by Xenakis, *Mists*

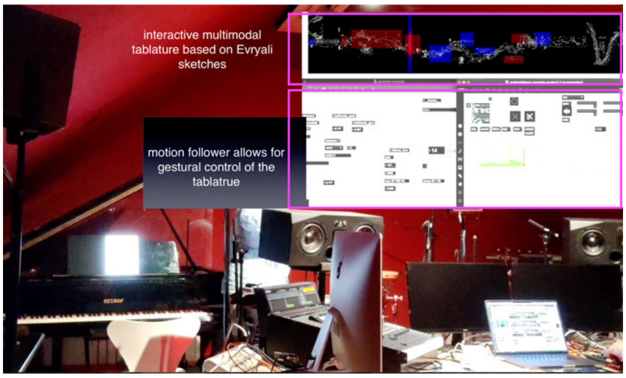

Figure 11. Snapshot from Video 5, annotated. Augmented interactive tablature based on *Evryali* sketches is used as a graphic score for a co-adaptive improvisation of a human performer, Pavlos Antoniadis, with SOMAX2, controlled by Mikhail Malt, including air gestures and piano based on Maurice Ravel's "Oiseaux Tristes"

5. SKETCHES AND EPISTEMIC BIASES IN ARTIFICIAL INTELLIGENCE

The reproduction of implicit and explicit human biases in algorithms has been a hot topic in AI research. Ethical questions about open AI applications have recently focused on discriminatory socio-political biases such as gender, race [11] and the Global North [12], whereas fundamental questions about implicit or explicit epistemic biases in relation to knowledge representation in AI have been less prominent [13]. While these two categories are fuzzy and far from incompatible [14], epistemic biases tend to encompass an endless range of *a priori* conceptions and models of human understanding, learning, knowledge, and judgment, which are uncritically implemented in AI applications [15]. As a result, systems architectures, as well as human-in-the-loop components, are constrained by traditional models of knowledge and fail to embrace the latest paradigm shifts in their target domains.

Both probabilistic architectures employed in the examples above, the gesture follower and the SOMAX2, exhibit strong implicit epistemic biases as far as knowledge representation in music is concerned. Their mutual reliance on the probabilistic navigation of audio files, either in relation to an incoming gesture in the case of gesture-follower, or in relation to pitch and *chroma* characteristics in SOMAX2, resonates with what has been called "the semantic blind spot of current inferential accounts of AI" [16]: Parmenidean probabilistic syntactic interchangeability of memoryless states produces no semantic relations or illusion of real effects of causality, unless *real* Heraclitean change is effectuated. And real change is effectuated by virtue of the unknown, rather than by virtue of known navigable corpora.

In retrospect, one could further claim that the implicit symbolic biases of the classic reproduction model, or even of its updates in forms such as the *high-modernist model of performance practice* [17], including: the fixity of musical scores in space and time; their parametric stratification; the symbol grounding problem [18] of musical parameters and *the inside – outside of time* problem that Xenakis and others have uttered, are transposed in straight-jacket fashion to a poor rendition of a complex dynamic system of improvisation [19], with biases such as: the limits of symbolic representation in relation to embodied experience "escaping computation"[3], the privileging of abstract sound relationships codified in scores over multimodal interactions embedded in social contexts, and the dimensionality reduction of complex and dynamic stances to simple parameters.

And yet: the concept of an emergent multiplicity of mappings between decoupled representation domains – sketches, scores, and multimodal data – is a promising one, in that it allows for unpredictable and personalized meaning-producing *inside time* interactions, even when the respective domains may seem to be highly sophisticated and responsive reshufflings of fixed *outside of time* timelines. The prospect of cracking the one-to-one mappings of sketches open, via their implicit one-to-many mappings and through their controversial existential repurposing into graphic scores affording similar and alien materials, is tempting, if only provisional, as any guerrilla tactic of malleable sketching should be.

6. CONCLUSIONS

Following a bottom-up trajectory, I have attempted to present a methodology that leads from deciphering and learning processes based on a meticulous analysis of sketches aiming at high modernist performance practice, to the open-ended use of sketches as graphic scores in Human-Machine comprovisation settings, including machine learning and Artificial Intelligence techniques. Such methodology reveals the inherent transitoriness of sketches as media, but also the importance of fluid forms of knowledge representation and of Human-Assisted Turing Machines amidst current trends and media-hypes in AI, which accentuate the blackboxness of Deep Learning based on Big Data and the "AI Effect" that renders "lighter" forms of AI obsolete, absorbing them into the broader category of computation. Featuring Iannis Xenakis's music for this purpose is far from random, given the dialectic clash between strict formalism and sensational surface, body and mind, scientific and artistic research epistemologies of his output.

Acknowledgments

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