ERC Advanced Grant 2019
Research proposal [Part B1]

Raising co-cr**ea**tivity in **c**yber-**h**uman Musicianship
REACH

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Proposal duration in months: **60**

Raising co-creativity in cyber-human musicianship

Digital societies will see the development of deep interweaving between human creativity and autonomous information-processing capabilities of virtual and physical objects, that turn joint human-machine activity into a mixed reality with symbiotic interactions. In the cultural or industrial domains, co-creativity between humans and machines will bring about the emergence of distributed information structures of a new kind that will profoundly impact individual and collective human development. With technologies allowing one to extract semantic features from physical and human signals, combined with generative learning of high-level representations, we are beginning to unveil the increasing complexity of cooperation, synergy or conflicts inherent to cyber-human networks. These hybrid micro-societies will need renewed frames of thoughts and actions in order to be fully understood and managed**.** To this end the REACH project aims at understanding, modeling, and developing co-creativity between humans and machines in the musical domain through improvised interactions allowing musicians of any level of training to develop their skills and expand their individual and social creative potential. Indeed, improvisation is at the very heart of all human interactions, and music is a fertile ground for developing models and tools of creativity that can be generalized to other activities, as in music the constraints are among the strongest to conduct cooperative or competitive behaviors that come together into highly integrated courses of actions. REACH will study shared musicianship occurring at the intersection of the physical, human and digital spheres, as an archetype of distributed intelligence, and will produce powerful models and tools as vehicles to better understand and foster human creativity in a world where it becomes more and more intertwined with computation.

Section a: Extended Synopsis of the scientific proposal (max. 5 pages)

Project outline

The research objective of this inter-disciplinary project is to model and enhance co-creativity as it arises in improvised musical interactions between human and artificial agents, in a spectrum of practices spanning from interacting with software agents to mixed reality involving instrumental physicality and embodiment. Such creative interaction strongly involves co-improvisation, as a mixture of more or less predictable events, reactive and planned behaviors, discovery and action phases, states of volition or idleness. Improvisation is thus at the core of this project and indeed a fundamental constituent of co-creative musicianship, as well as a fascinating anthropological lever to human interactions in general.

The outline of the project unfolds as follows:

- ✓ **Understanding**, modelling, implementing music generativity and improvised interaction as a general template for *symbiotic interaction between humans and digital systems* (cyber-human systems)
- ✓ **Creating** the scientific and technological conditions for *mixed reality musical systems*, based on the interrelation of creative agents and active control in physical systems.
- ✓ **Achieving** distributed co-creativity through complex *temporal adaptation of creative agents* in live cyber-human systems, articulated to field experiment in *musical social sciences*.

These three directions are already innovative and ambitious in their own right. Setting up a synergy between them, in order to foster understanding of co-creativity between natural and artificial beings on a socially significant scale, is an entirely novel initiative. It is the first organized interdisciplinary attempt at deciphering and shaping cyber-human co-creativity, an emerging field of study obviously called to considerable developments in the digital era. Revealing the mechanisms of co-creativity in music will also be a remarkable projector on creativity in general, as music is one of the most highly organized, interactive and complex human activity — at the same time an abstract, sensitive and physical one, yet profoundly shaped by communication and improvisation, and as such a powerful metaphor of human creative interactions.

We will put in place a research ecosystem allowing us to answer two central questions:

- ✓ How to ***augment the digital*** *agents* capacities with enhanced computational creativity as well as with cyber-physical extensions, so *they can develop convincing interactions with humans*
- ✓ How to ***augment the human*** *capacities* by expanding their individual and social creative potential, through novel collaborative strategies and mixed reality, so *they can naturally immerse themselves in complex schemes involving digital intelligence.*

In REACH, co-creative interactions between humans and machines will be studied dynamically from different perspectives (music sciences, social sciences, computer science) in order to highlight the combined conditions under which these interactions occur, their temporal behavior, adaptive dynamics and control strategies, so as to drastically enhance their creative potential.

We emphasize the fact that shared creativity is *an emerging process, resulting from complex interactions and multimodal, cross feed-back loops between natural and artificial actors*, a process that cannot be reduced to an agent's production considered in isolation, or to a single layer of technical skill. *This conception neutralizes the endless philosophical question of whether artificial entities can be qualified as "creative"* and safely shifts the REACH research interest towards the positive exploration of the best possible models and tools to allow for co-creative cycles to bootstrap and settle.

We also believe that "computational creativity" will socially take root in a decisive way when it eventually creates the conditions of emergence of cyber-human co-creativity, and when it eventually clings to an augmented physical reality allowing humans to experience a rewarding embodied relation. *To this effect REACH will work towards bridging the gap between abstract computational logics and mixed reality experience anchored in creative musical instruments.* In such configurations of physical interreality (a mixed reality where the physical world is actively modified by human action), the human subjects participating to co-creative scenarios will be directly engaged in the digital, the physical and the social dimensions of the experience. Such a seamless integration of cyber to physical to human will be the next frontier in Creative Artificial Intelligence [Boden 1998, Briot & al 2019] and REACH aims at being a powerful instrument towards it. So, REACH will implement interreality through *Creative Instruments*, music instruments that embed an unheard level of digital intelligence and musicianship making them full partners of humans in co-creative scenarios.

General background

In all sectors of human activity, we see coming new forms of blending between human creativity and autonomous information processing capabilities of physical objects that turn joint human machine interaction into an augmented and mixed reality. In the cultural, artistic, educative or economical domains, co-creativity between humans and machines will bring about the emergence of distributed information structures of a new kind, as in networked ambient intelligence or in artistic performances of mixed artificial and human agents. These practices will disrupt known cultural orders and profoundly impact human development [Boden 1998] [Assayag 2016]. With technologies allowing one to extract semantic features from physical (e.g. acoustic, light) and human (e.g. physiological, gestural, vocal) signals [Dubos & al 2017] [Boyer & al 2017], combined with novel generative learning of symbolic representations [Briot & al 2019], we are beginning to unveil the increasing complexity of cooperation, synergy or conflicts inherent to cyber-human networks. These new cooperative micro-societies need fresh conceptual and technological frames in order to be fully understood. Our project aims at bringing a decisive contribution to solving this problem in the creative and artistic domains.

By understanding, modelling, and developing co-creativity between human and machines in the musical domain through improvised interactions REACH will allow musicians of any level of training to develop their skills and expand their individual and social creativity. Indeed, improvisation is at the very heart of all human interactions, and music is a fertile ground for developing models and tools of creativity that can be generalized to other activities, as in music the constraints are among the strongest to conduct cooperative behaviors that merge into highly efficient and meaningful courses of actions [Sawyer 2000]. ***REACH will study shared musicianship occurring at the intersection of the physical, human and digital spheres as an archetype of distributed intelligence, and will produce powerful models and tools as vehicles to better understand and foster individual and collective human creativity*** in a world where it becomes more and more intertwined with computation.

In addition to the exploration of computational creativity [Wiggins 2006, Colton and Wiggins 2012] in "soft" human-computer configurations involving improvised musical interactions and displaying distributed co-creative behaviors, REACH assumes that cyber-human synergies will happen optimally when users are put in a situation where they experience full embodiment [Scurto & al 2017] in their relation to artificial agents, through the physicality of familiar creative devices such as musical instruments. The musical market has recently introduced cyber-physically augmented music instruments (Smart Instruments) such as the HyVibe Guitar, that brings embedded computing, mechatronics and physical modelling straight under the fingers of the musician [Meurisse & al 2014]. Smart Instruments are a first step toward the blending of sophisticated information processing power down to the core physics of the instruments in order to enhance their sound universe and their interactive power [Benacchio & al 2016]. However, at this stage, these devices do not display musical creativity, in effect, they lack machine musicianship (the capacity to process and create music information at a structural, semantic level), as well as digital intelligence in interaction strategies or generative autonomy.

By bridging the gap between smart instruments with active acoustic control on the physical side, and digital intelligence for co-creative interaction on the logical side, REACH will make possible the advent of Creative Instruments: physical instruments loaded with active control and creative agents. A Creative Instrument will be able to listen to the musician playing, learn music structures and style on-line and autonomously enter into a creative dialog with the player. Such conditions will install a mixed reality framework, with cross-feedback loops occurring through physical and perceptual channels between human and artificial agents, a novel experience in artistic development.

Originality and impact

A major originality of this project is to constitute the first attempt to build a scientific and technological mesh of knowledges and tools around computational co-creativity and musical improvisation through a highly interdisciplinary approach combining computational sciences of music, artificial intelligence, anthropology of improvised knowledges and practices, and mixed reality. It is also the first time that the notion of improvisation is brought as a general scheme of cyber-human communication targeting creative behaviors, and that methods for augmenting human capacities and for enhancing computational creativity are brought together to model symbiotic interaction. The REACH project will provide theoretical foundations, technologies, software suites and experimental data and make them available in open-access to all the research community, and to other communities as well (e.g. artists, instrument makers, game developer, medias). REACH co-creative instruments will bring about the long-awaited convergence between physicality, information processing and creativity, in a manner that will be maneuverable and enjoyable by all, at all levels of skills and expertise. Such

progress will be likely to disrupt artistic and social routines, as well as amateur and professional music practices, eventually impacting music industry in a game-changing way. As an illustration, in 2014, amateur and professional guitarists spent more than $4.25 billion on buying musical gear. However, it has become very difficult to retain new buyers (90% of guitar buyers stop playing in the first year, according to Fender). By adapting to individual skills, levels and musical tastes, Creative Instruments will increase the intensity and pleasure of creative use, contributing to human development and attaching users to artistic creativity in a constantly renewed esthetic experience.

Cyber-human co-creativity is strongly felt when two features of improvisation linked to emergence [Canonne & Garnier 2011] and non-linear dynamics [Mouawad & Dubnov 2017] are present:

- ✓ **emergence** of cohesive concomitant behaviors that are not reducible to, nor explainable by the mere individual processes of agents
- ✓ **apparition** of non-linear regimes of event and structure formation, leading to rich musical co-evolution of forms.

Our assumption is that these surging phenomena result from *cross learning processes between agents involving complex feed-backs loops and reinforcement mechanisms,* and our project will pioneer the way to create the optimal conditions to accommodate these phenomena. A major consequence of co-creativity in that sense is that it will then change the states and behavior of individual agents, and so participate in their evolution in terms of knowledge and skills. To that extent, the vision of computational co-creativity foreseen by REACH is totally novel with respect to state-of-the-art works, and specially with respect to recent heavy-weight research programs such as Google Magenta, Sony Flow Machines, MIT Media-Lab Opera of the future, or Spotify Creator Technology Lab (see e.g. [Roberts & al 2018], [Hadjeres & al 2017]), who are generally centered on generative style learning and do not address directly, as we will, the co-action and emergence problem.

In REACH, human-machine co-creative strategies, based on the integration of artificial listening, interactive learning, structure discovery, mixed reality, and social science assessment, will provide a new ground for understanding symbiotic interaction between the digital, the physical and the human world, with deep repercussions on the unfolding of individual and collective creativity.

Methodologies

The fundamental working hypothesis behind REACH is that one has to operate in two symmetrical and converging directions in order to *simultaneously raise* the capacity of human and cyber agents, so that they meet at the point where *synergistic effects may happen and make way for co-creative behavior*. The two central tasks (1) and (2) of the project will thus follow this scheme:

1. **Raising Cyber Reach** (RC): Augment the digital agents' abilities with enhanced computational creativity, autonomy and multimodal sensitivity to context, as well as with cyber-physical extensions in mixed reality instruments, so they can enter into a convincing expert interplay with humans.
2. **Raising Human Reach** (RH): Augment the human abilities, by interfacing them into cross-modal, embodied mixed reality so they can interact in a natural and creative way with artificial agents, and by expanding their reach through novel collaborative strategies infused by social sciences field experiments.

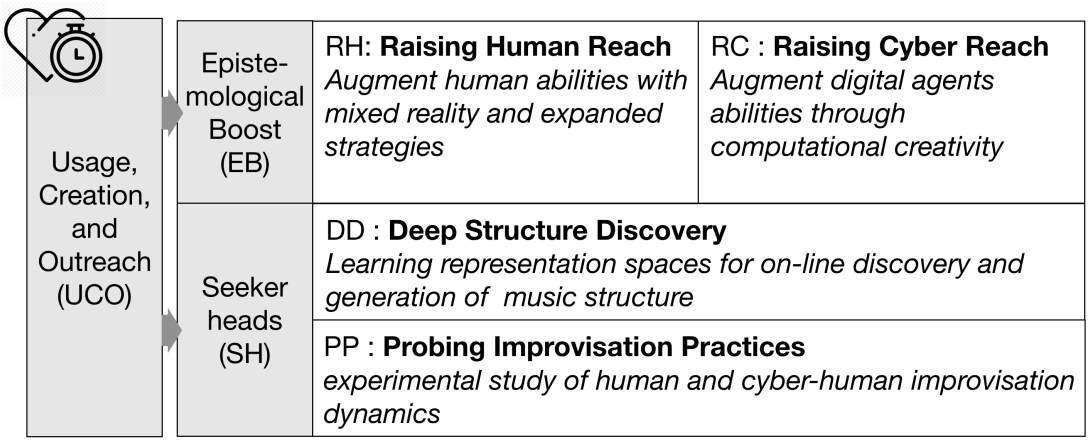
In order to provide solid foundations and tools to sustain *this double motion from Cyber to Human and from Human to Cyber* (1) and (2), we will surround it with two domains of action (3) and (4):

3. **Deep Structure Discovery** (DD): Machine Learning of complex multi-variate signals involving *structure discovery and knowledge extraction* in musical signals
4. **Probing Improvisation Practices** (PP): Field research providing human (or combined cyber-human) data, experimental assessment and heuristic guides for model parametrization through an *anthropology of improvisation practices, knowledges and processes*.

RH and RC form the **Epistemological Boost** (EB) component of our research strategy: by symmetrically augmenting humans and artificial agents until they come together at their co-creative nexus by producing emergent information, we will achieve an epistemological leap [Bachelard 1934] beyond the blocking idea that artificial systems cannot be creative by themselves. This turn things around in stating that creativity is not a state anyway, but rather a dynamical effect of interaction in a complex system, likely to show that *radical novelty* already identified as a characteristic of Emergence [Corning 2002]. *By building on this epistemological boost, REACH will be able to model deep interactions that in turn will trigger co-creative behaviors.*

DD and PP form the **Seeker Heads** (SH): a cluster of exploratory researches in music structure discovery and improvisation shaping, that will sustain and feed the EB component by providing general learning models, creation heuristics, behavioral examples, and social-science based protocols and data.

These two component EB and SH will be articulated by a **Usage, Creation, and Outreach** (UCO) package acting as a *project clock*, or a heart-beat pulsating the timing of a series of iteration between modelling, prototyping, experimenting, and creation / outreach. Going through fast research and development cycles favoring interaction between all work packages, with regular milestones and deliverables, it will smooth-out the interdisciplinary cooperation and prevent unforeseen problems that could potentially seize up the organization of the project. UCO will clock at several nested periodicities (bimonthly, semester, year, biennial) to schedule coordination meetings, delivery checking, scientific seminaries, local and far-reaching international workshops and dissemination events including tracks in major conference. *Although REACH is high-risk high-gain, this heart-beat of animation, stimulation and coordination will provide a high level of confidence and security in smoothing the pace of research and production interaction, inside the PI's team and with external collaborators as well.*



Inside this work program, we will use methods drawn mostly from (1) Interactive computational creativity, (2) mixed reality augmentation of music instruments (3) machine learning and musical information dynamics, and (4) social sciences and anthropology of improvised practices. *Such a high level of inter-disciplinarity in the REACH project is realistic since the PI has a unique background in heading for six years a world-renowned laboratory encompassing all sciences of music and sound, where he has successfully organized wide-ranging, multi-domain research strategies.* The PI will nevertheless surround his team with a network of expert researchers or economical actors, from which he will seek one-off expertise in well-defined perimeters, at various stages of the project, notably in the fields of Musical Information Dynamics and cognition, Social Science / Anthropology, Augmented reality and Acoustics.

Interactive Computational creativity and mixed reality will be at the core of the Epistemological Boost (EB). Improvised interaction between humans and digital agents [Blackwell 2012] is dependent on mastering artificial creativity, which brings together several key research issues: knowledge, perception and intention modeling, real-time interactive learning — featuring cross feed-backs between human and digital entities that continuously modify the context (moving target)—, time structure formalization. Mixed reality will be instantiated by Creative Instruments reassembling active acoustics and creative agents. *Going beyond state-of-the-art cyber-physical systems (that create a continuity between the digital and the physical worlds), REACH will promote cyber-human systems that create a continuity between digital and human creativity.*

Machine Learning and Musical Information Dynamics of complex multi-variate signals such as polyphonic musical signals, involving structure discovery and knowledge assessment, will be essential to understand and process (often in real-time) the variety of signals exchanged by humans and creative agents. These signals bear implicit multi-dimensional and multi-scale semantic structures that are hard to tract computationally, but that are nonetheless necessary for machine perception and learning to work properly. Representation learning of these structures, through artificial intelligence methods such as statistical learning and deep learning [Esling & al 2018] will be at the core of the Seeker Heads (SH). Musical Information Dynamics (MID) characterize semantically important changes in information contents of audio signals [Abdallah & Plumbey 2009] [Dubnov 2010]. REACH will extend state-of-the-art MID towards longer term correlations and attention control, in order to address the question of intention and decision over larger scale structures and bigger time spans. *This will bring a better understanding of joint cognition and creativity and will feed the design of creative agents. It will also help us to assess that co-creativity is actually boosted by (EB), by checking information measures*

correlated to variations in surprise, interest, flow, affects, and analyzing their tendencies over different types and scales of interactions.

Social Science, anthropological approaches will be used to observe, analyze, archive and understand improvisational practices and knowledges between humans, as well as between humans and machines. Data from these studies will help guide the conception of the perceptual, generative and interaction models in EB and DD. This work at the interface of technology, artistic practices and urban anthropology, will proceed on live performance involving different modes of human-machine interaction, in diverse cultural background. It will use the methods of the field survey in the usual sense of ethnomusicology: performance data collecting, audio-visual and gestural capture of live context of musical sessions, interviews with participants (musicians, audience), sessions of re-listening, analysis of the musical contents archived by the software prototypes. A series of questions will be examined: How do the musicians react to the computer actions? Does it influence the way human musicians play themselves? Do they perceive computer productions as intentional, on-purpose? Do they perceive computer interaction as realistic in the sense that humans could produce it, or rather as un-human, thus potentially bending towards totally unheard artistic forms and aesthetics? *This will bring understanding of joint cognition and action from the human science angle and will complement and correlate the "objective" MID assessment of co-creativity emergence, by "subjective" survey of human behavior and discourses in creative situations.*

Feasibility

Host Institution (HI) IRCAM, founded by famous composer and conductor Pierre Boulez, is the largest institution in the world gathering scientific research, technology engineering, contemporary music production, concert season and teaching. It offers absolutely unique conditions for REACH researches that seat at the crossing of several scientific, aesthetic, social and technological domains. The hosting Lab STMS (Sciences and technologies of music and sound, a joint operation by IRCAM, CNRS and Sorbonne University) inside IRCAM is world leader in Sound and Music Computing. The hosting team in STMS, called Music Representation, is headed by the PI and internationally renowned in Musical Informatics and Creative Interaction.

The REACH team itself will be formed by the PI (40% of FTE time) plus three postdocs (PoD), three PhD students and a research assistant. The couples (PoD1, PhD1) will focus on the EB cluster, (PoD2, PhD2) on the PP task, and (PoD3, PhD3) on the DD task, with several interactions and crossings. The hosting lab will provide a great amount of punctual expertise as needed in the different tasks of the project Pr. Philippe Esling is an expert in Creative Artificial Intelligence and the founder of the ACIDS research group (Artificial Creative Intelligence and Data Science). The S3AM team (acoustics, mechatronics, signal processing, and physical modelling, head: T. Hélie), ISMM team (embodiment, human gesture, head: F. Bevilacqua), and PDS (cognition, perception, computational neurosciences, head: P. Susini) are recognized leaders in their domain and will provide invaluable punctual expertise in these fields. The IRCAM Music Production and Teaching Department, used to manage international seasons of artistic productions, will be decisive in supporting the PI for experimental sessions and artistic outreach.

Regular international collaborators of the PI in Europe, USA and Japan, will provide punctual expertise or service delivery where needed : the award winning Hyvibe high tech-sound company, on prototyping and experimenting the Creative Instruments; UCSD Lab CREL (Center for Research in Entertainment and Learning, (Dir. Shlomo Dubnov, a recognized leader in Musical Information Dynamics) on machine learning, artificial listening and edutainment applications ; EPFL Meta Media Center / Montreux Jazz Heritage Lab (Resp. Alain Dufaux) will give access to huge amounts of annotated live musical data through the Heritage Montreux Jazz Festival Archive, a registered UNESCO Immaterial Memory of the World Heritage; EHESS CAMS Lab (Ecole des Hautes Etudes en Sciences Sociales, Centre d'Analyse et de Mathématique Sociales, PI: Marc Chemillier) will provide social science / anthropological method and expertise for the PP task. The PI also maintain continuous collaboration and PhD students exchange with several labs at Tokyo University (Pr. Harada Cyber Physical Systems Lab, Pr. Hirose Cyber Laboratory) and Tokyo Metropolitan University (Pr. Ikei Virtual Reality and Ultra Reality Lab) who will provide expertise on cyber-physical systems, mixed reality and deep learning theory and practice.

References

Abdallah S.A. and M. Plumbley, D., Information dynamics: patterns of expectation and surprise in the perception of music, Connection Science, Vol. 21, No. 2. (2009), pp. 89-117.

Allombert, A., Desainte-Catherine, M., **Assayag**, G., « Towards an hybrid temporal paradigm for musical composition and performance », Computer Music Journal, 2012, vol. 4, n° 36

Allombert, A., Desainte-Catherine, M., and **Assayag**, G. Iscore: a system for writing interaction. Proc.3rd international Conference on Digital interactive Media in Entertainment and Arts, DIMEA '08, vol. 349, 360-367. ACM, New York, 2008

Allombert A., Desainte-Catherine M., Larralde J. and **Assayag** G., «A system of Interactive Scores based on qualitative and quantitative temporal constraints», Proc. of the 4th International Conference on Digital Arts (Artech 2008), Porto, 2008.

Allwood, J., Linguistic communication as action and cooperation. Gothenburg monographs in linguistics, 1976, vol. 2, p. 637-663.

Agon, C., Bresson, J., **Assayag**, G., OpenMusic: Design and Implementation Aspects of a Visual Programming Language », 1st European Lisp Symposium - ELS'08, Bordeaux, 2008

Allombert, A., **Assayag**, G., Desainte-Catherine, M., « A system of Interactive Scores based on Petri Nets », SMC'07 - 4th Sound and Music Computing Conference, Lefkada, pp. 158-165, 2007

Andreatta M., Musique algorithmique, In N. Donin et L. Feneyrou (eds), Théorie de la composition musicale au XXe siècle, Symétrie, Paris, 2013

Arom, S., African Polyphony and Polyrhythm: Musical Structure and Methodology, Cambridge University Press, 1991 - 668 pages.

Argamon, S., Burns ,K., and Dubnov, S., (eds), "The Structure of Style: Algorithmic Approaches to Understanding Manner and Meaning", Springer SBM, 2010

Assayag, G., Improvising in Creative Symbolic Interaction. In Smith; Chew; Assayag (Eds), Mathematical Conversations: Mathematics and Computation in Music Performance and Composition, World Scientific; Imperial College Press, pp.61 - 74, 2016

Assayag,, G. Creative Symbolic Interaction, 40th Intl. Comp. Mus. Conf. and 11th Sound and Music Comp. Conf. (ICMC / SMC joint conf.), Athenes, Greece, pp 1-6, 2014.

Assayag, G., Truchet, C. (Eds) « Constraint Programming in Music », Constraint Programming in Music, ISTE Ltd and John Wiley & Sons Inc, 256 p., 2011

Assayag, G., Bloch, G., Cont, A., Dubnov, S., Interaction with Machine Improvisation, in S.Argamon, S. Dubnov and K.Burns (Eds) The Structure of Style: Algorithmic Approaches to Understanding Manner and Meaning, Springer, pp.219-245, 2010

Assayag, G., Gerzso, A., « New Computational Paradigms for Computer Music », New Computational Paradigms for Computer Music, ed. Gérard Assayag et Andrew Gerzso. (Ircam/Delatour), 2009

Assayag, G., Bloch, G., Navigating the Oracle: a Heuristic Approach, International Computer Music Conference '07, Copenhagen, 2007, pp. 405-412

Assayag, G., Bloch, G., Chemillier, M., OMax-Ofon, Sound and Music Computing SMC'06, Marseille, 2006

Assayag, G., Bloch, G., Chemillier, M., Improvisation et réinjection stylistiques. Le feed-back dans la création musicale contemporaine - Rencontres musicales pluri-disciplinaires, Mar 2006, Lyon, France.

Assayag, G., Bloch, G., Chemillier, M., Cont, A., Dubnov, S., Omax Brothers : a Dynamic Topology of Agents for Improvisation Learning, Audio and Music Computing for Multimedia, ACM Multimedia '06, Santa Barbara, 2006

Assayag, G., Dubnov, S., « Improvisation Planning and Jam Session Design using concepts of Sequence Variation and Flow Experience », Sound and Music Computing 2005, Salerno, 2005

Assayag, G., Dubnov, S., Using Factor Oracles for machine Improvisation, Soft Computing, Springer Verlag, 2004, 8 (9), pp.604-610, 2004.

Assayag, G., Dubnov, S., Delerue, O., Guessing the Composer's Mind : applying Universal Prediction to Musical Style, ICMC: International Computer Music Conference, Beijing, 1999

Assayag, G., Agon, C., Fineberg, J., Hanappe, P., An Object Oriented Visual Environment for Musical Composition, ICMC: International Computer Music Conference, Thessaloniki, 1997, pp. 364-367

Assayag G., Agon, C., OpenMusic Architecture. International Computer Music Conference ICMC'96, Hong Kong 1996.

Assayag, G., Visual Programming in Music, International Computer Music Conference ICMC'95, Banff, 1995, pp. 73-76

Arias, T., Desainte-Catherine M., and Dubnov, S., Automatic Construction of Interactive Machine Improvisation Scenarios from Audio Recordings, 4th Intl Workshop on Musical Metacreation, International Conference on Computational Creativity, Paris, 2016

Auslander, Ph. Liveness: Performance in a mediatized culture. New York: Routledge, 1999.

Ayad, L., Chemillier, M., Pissis, S., , Creation Improvisation on Chord Progressions using Suffix Trees, Journal of Mathematics and Music, vol 12 (3), 2018.

Bachelard, G., La formation de l'esprit scientifique, Paris, Alcan, 1934 (reprint. Paris PUF coll. « Quadrige », 2013)

Bamberger, J., Discovering the musical mind: A view of creativity as learning. New York, NY: Oxford University Press, 2013.

Ban, Y.,, T. Narumi, T. Fujii, S. Sakurai, J. Imura, T. Tanikawa and M. Hirose: Augmented Endurance: Controlling Fatigue while Handling Objects by Affecting Weight Perception using Augmented Reality, CHI2013, pp.69-78. 2013.

Boden, M., Computers models of creativity. AI Magazine 30(3): 23–34. 2009

Boden M.A., Creativity and Artificial Intelligence. Artificial Intelligence, 103:347-356, 1998.

Boden, M.A., Dimensions of Creativity, M. A. Boden (ed.), The. MIT Press, Cambridge, Mass., 1996

Boden, M.A., The Creative Mind: Myths and Mechanisms. New York: Basic Books. 1991

Bailey, Derek, L'improvisation. Sa nature et sa pratique dans la musique, trad. Isabelle Leymarie, Paris, Outre Mesure, 1999.

Berliner, Paul. Thinking in Jazz: The Infinite Art of Improvisation. Chicago: University of Chicago Press, 1994.

Benacchio, S., Mamou-Mani, A., Chomette, B., Finel, V. Active control and sound synthesis—two different ways to investigate the influence of the modal parameters of a guitar on its sound. Journal of the Acoustical Society of America, 139 (3), pp.1411, 2016

Benacchio, S., Mamou-Mani, A., Chomette, B., Causse, R. Active control applied to string instruments. Société Française d'Acoustique. Acoustics 2012, Apr 2012, Nantes, France. 2012.

Bengio, Y., Boulanger-Lewandowski, N., & Pascanu, R. (2012). Advances in optimizing recurrent networks. 2013 IEEE International Conference on Acoustics, Speech and Signal Processing, (2012): 8624-8628.

Bimbot, F., E. Deruty, G. Sargent, and E. Vincent. System & Contrast: a polymorphous model of the inner organization of structural segments within music pieces. Music Perception 33(5):631–661. 2016

Bigo, L., M. Giraud, R. Groult, N. Guiomard-Kagan, and F. Levé. "Sketching sonata form structure in selected classical string quartets." In Proceedings of the International Society for Music Information Retrieval Conference. pp. 752–759. 2017.

Birkhoff, G.D., Aesthetic Measure, Harvard Univ. Press, 1933.

Blackwell, T., Oliver Bown & Michael Young. Live Algorithms: Towards Autonomous Computer Improvisers. In Jon McCormack & Mark d'Inverno, editeurs, Computers and Creativity, pages 147–174. Springer Berlin Heidelberg, 2012.

Bloch, G., Dubnov, S., **Assayag**, G., « Introducing Video Features and Spectral Descriptors in the OMax Improvisation System », International Computer Music Conference ICMC'08, Belfast, 2008

Butler, M. Playing with Something That Runs. Technology, Improvisation, and Composition in DJ and Laptop Performance, Oxford University Press, 2014.

Bonnasse-Gahot, L., An update on the SOMax project, IRCAM Report, Soma v0.1.3 (2014)

Boyer, E., Arthur Portron, Frédéric Bevilacqua, Jean Lorenceau. Continuous Auditory Feedback of Eye Movements: An Exploratory Study toward Improving Oculomotor Control. Frontiers in Neuroscience, 2017, 11

Briot, J.-P. , Hadjeres G., and Pachet, F.D., Deep Learning Techniques for Music Generation, Computational Synthesis and Creative Systems, Springer, 2019

Bresson, J., Guédy, F., **Assayag**, G., Musique Lab 2: From computer-aided composition to music education, Journal of Music, Technology and Education, Intellect, 2013, 5 (3), pp.273-291.

Bresson J., Agon C., **Assayag** G., Visual Lisp/CLOS Programming in OpenMusic. Higher-Order and Symbolic Computation. Mars 2009, vol. 22, n° 1, p. 81-111

Canonne, C., Garnier, N., "A Model for Collective Free Improvisation", Mathematics and Computation in

Music. Third International Conference MCM 2011, IRCAM, Paris, France, June 15-17, 2011. Proceedings, Springer, 2011.

Canonne, C., Garnier, N., Cognition and Segmentation In Collective Free Improvisation: An Exploratory Study. International Conference on Music Perception and Cognition, 2012, Thessaloniki, Greece.

Carpentier, G., **Assayag**, G., Saint-James, E. « Solving the Musical Orchestration Problem using Multiobjective Constrained Optimization with a Genetic Local Search Approach », Journal of Heuristics, 2009.

Carpentier, G., Tardieu, D., **Assayag**, G., Rodet, X., Saint-James, E., (2007) « An Evolutionary Approach to Computer-Aided Orchestration », EvoMUSART, vol. LNCS 4448, Valence, 2007, pp. 488-497

Carsault, T. Nika, J. & Esling, P. Using musical relationships between chord labels in Automatic Chord Extraction tasks. 19th ISMIR Conference (ISMIR2018), Paris, France, 2018

Clayton, Martin. What is entrainment? Definition and applications in musical research. Empir. Musicol. Rev. 7, (2012) 49–56.

Chemillier, M. De la simulation dans l'approche anthropologique des savoirs relevant de l'oralité : le cas de la musique traité avec le logiciel Djazz et le cas de la divination, Transposition, Hors-série n°1, Musique, histoire, société, 2018

Chemillier, M. Nika Jérome, « Étrangement musical » : les jugements de gout de Bernard Lubat à propos du logiciel d'improvisation ImproteK, Cahiers d'ethnomusicologie, n° 28, 2016, pp. 61-80.

Chemillier, M. Jazz et... musiques électroniques, P. Carles, A. Pierrepont (éds.), Polyfree. La jazzosphère (et ailleurs) : une histoire récente (1970-2015), Paris, Outre Mesure, ch. 3, pp. 43-54, 2016.

Chemillier, M., Ruse et combinatoire tsigane. De la modélisation informatique dans les répertoiresmusicaux traditionnels (à propos du livre de Victor A. Stoichita : Fabricants d'émotion. Musique et malice dans un village tsigane de Roumanie), L'Homme, n° 211, 2014, pp. 117-128.

Chemillier, M., Fieldwork in Ethnomathematics, Nick Thieberger (ed.), The Oxford Handbook of Linguistic Fieldwork, Oxford University Press, 2011, chapter 14, pp. 317-344.

Chemillier, M. L'improvisation musicale et l'ordinateur. Transcrire la musique à l'ère de l'image animée, Terrain, n° 53 « Voir la musique », 2009, pp. 67-83.

Chemillier, M., Toward a formal study of jazz chord sequences generated by Steedman's grammar. Soft Computing, Vol. 8, No. 9, pp. 617–622, 2004.

Chemla-Romeu-Santos, A., Ntalampiras, S., Esling, P., Haus G., and **Assayag**, G., Cross-Modal Variational Inference for Bijective Signal-Symbol Translation, 22nd International Conference on Digital Audio Effects DAFx 2019

Chew, E.. From sound to structure: Synchronising prosodic and structural information to reveal the thinking behind performance decisions. In C. Mackie (ed.): New Thoughts on Piano Performance, selected papers from the 2013 and 2015 London International Piano Symposium. Kindle Amazon, 2017

Chew, E. Mathematical and Computational Modeling of Tonality: Theory and Applications. International Series in Operations Research and Management Science, New York, NY: Springer, 2014

Cholakis, Ernest, Sound Analysis of Swing in Jazz Drummers: An Analysis of Swing Characteristics of 16 well known Jazz Drummers, 1995, http://www.numericalsound.com/sound-analysis.html

Collins, D. A synthesis process model of creative thinking in music composition. Psychology of Music, 33(2): 193-216, 2005.

Cook, N., Beyond the Score: Music as Performance. Oxford, UK: Oxford University Press, 2013

Conklin, D., Multiple viewpoint systems for music classification. Journal of New Music Research, Volume 42, Number 1, pp. 19-26, March 2013

Conklin, D. Music Generation from Statistical Models , Proceedings of the AISB 2003 Symposium on Artificial Intelligence and Creativity in the Arts and Sciences, Aberystwyth, Wales, 30– 35, 2003.

Crestel, L. Esling, P. Ghisi, D. Meier, R. Generating orchestral music by conditioning SampleRNN, Timbre 2018: Timbre is a many-splendored thing. Montreal, 2018.

Crestel, L., Esling. P., Live Orchestral Piano, a system for real-time orchestral music generation. 14th Sound and Music Computing Conference 2017, Jul 2017, Espoo, Finland. pp.434, 2017

Crochemore, M., Ilie L., Seid-Hilmi, E., The Structure of Factor Oracles, Int. J. Found. Comput. Sci. 18(4), 781–797 (2007).

Colton, S. and Wiggins, G. A.. Computational creativity: The final frontier? In Proceedings of 20th European Conference on Artificial Intelligence (ECAI), pages 21-26, 2012

Cont, A., Dubnov, S., **Assayag**, G., On the Information Geometry of Audio Streams with Applications to Similarity Computing, IEEE Trans. on Audio, Speech and Language Processing, 19 (4), pp.837-846, 2011

Cont, A., Dubnov, S., **Assayag**, G., GUIDAGE: A Fast Audio Query Guided Assemblage, International Computer Music Conference, ICMC'07, Copenhagen, 2007

Cont, A., Dubnov, S., **Assayag**, G., Anticipatory Model of Musical Style Imitation using Collaborative and Competitive Reinforcement Learning , in Butz, M., Sigaud O., and Baldassarre G. (eds.), Anticipatory Behavior in Adaptive Learning Systems, Lecture Notes in Computer Science, Springer Verlag, Berlin, vol. 4520, pp. 285-306, 2007

Cont, A., Dubnov S., **Assayag**, G., A Framework for Anticipatory Machine Improvisation and Style Imitation", Adaptive Behavior in Anticipatory Learning Systems / Simulation of Adaptive Behavior (SAB 2006) Rome, Italy, 2006.

Corning, P. A., The Re-Emergence of "Emergence": A Venerable Concept in Search of a Theory, Complexity, 7 (6): 18–30, 2002

Daikoku, T., Musical Creativity and Depth of Implicit Knowledge: Spectral and Temporal Individualities in Improvisation. Frontiers in Computational Neuroscience vol.12. 2018.

Déguernel, K., Vincent, E., **Assayag**, G., Learning of Hierarchical Temporal Structures for Guided Improvisation. Computer Music Journal, accepted 2019 .

Déguernel, K., Vincent, E., **Assayag**, G., Probabilistic Factor Oracles for Multidimensional Machine Improvisation. Computer Music Journal, 42:2, article 4, Summer 2018

Deguernel, K., Nika, J., Vincent, E., **Assayag**, G. Generating Equivalent Chord Progressions to Enrich Guided Improvisation : Application to Rhythm Changes. SMC 2017 - 14th Sound and Music Computing Conference, Espoo, Finland. pp.8, 2017

Deguernel, K., Nika, J., Vincent, E., **Assayag**, G., Using Multidimensional Sequences For Improvisation In The OMax Paradigm. 13th Sound and Music Computing Conference, Hamburg, Germany, 2016.

Doffman, Mark, Groove! Its Production, Perception, and Meaning in Jazz, M.A. Thesis, U. of Sheffield, 2005.

Doras, G., Esling, P., & Peeters, G. On the use of u-net for dominant melody estimation in polyphonic music. IEEE International Workshop on Multilayer Music Representation, Milano, Italy, pp. 66-70 (2019)

Donze, A., S. Libkind, S.A. Seshia, D. Wessel, Control improvisation with application to music. Technical report No. UCB/EECS-2013-183. EECS Department, University of California, Berkeley, 2013.

Dubnov, S., Characterizing Time Series Variability and Predictability from Information Geometry Dynamic, vol. 8085 of the Lecture Notes in Computer Science series, pp. 658-668, Springer, 2013

Dubnov,S., Musical Information Dynamics as Models of Auditory Anticipation, in Machine Audition: Principles, Algorithms and Systems, ed. W. Weng, IGI Global publication, 2010

Dubnov, S., Unified View of Prediction and Repetition Structure in Audio Signals with Application to Interest Point Detection, IEEE Trans. on Audio, Speech and Language Proc., Vol. 16, No. 2, pp. 327-337, 2008

Dubnov, S., **Assayag**, G., Music Design with Audio Oracle using Information Rate. First International Workshop On Musical Metacreation (Mume 2012), Oct 2012, Palo Alto, United States. pp.1-1, 2012.

Dubnov, S., **Assayag**, G., Cont, A., Audio Oracle Analysis of Musical Information Rate, Proceedings of IEEE Semantic Computing Conference (ICSC2011), United States. pp.567—571, 2011

Dubnov, S., **Assayag**, G., Cont, A., Audio Oracle: A New Algorithm for Fast Learning of Audio Structures, International Computer Music Conference, Copenhaguen, 2007

Dubnov, S., **Assayag**, G., Lartillot, O., Bejerano G., Using Machine-Learning Methods for Musical Style Modeling, IEEE Computer, vol. 10, n° 38, Octobre, 2003

Dubnov, S., **Assayag**, G., Universal Prediction Applied to Stylistic Music Generation, in Assayag, G., Feichtinger, H.G., Rodrigues, J.F. (eds.), Mathematics and Music, Springer-Verlag, Berlin, pp. 147-158, 2002

Dubnov, S., Burns, K.,Kiyoki, Y., Cross-Cultural Multimedia Computing - Semantic and Aesthetic Modeling. Springer Briefs in Computer Science, Springer 2016

Dubnov, S., Cont, A., **Assayag**, G., Audio Oracle: A New Algorithm for Fast Learning of Audio Structures », International Computer Music Conference, Copenhaguen, 2007

Dubnov, S., McAdams, S., and Reynolds, R., Structural and Affective Aspects of Music from Statistical Audio Signal Analysis, Journal of the American Society for Information Science and Technology, 57(11):1526–1536, 2006

Dubnov S., and Surges, G., Delegating Creativity: Use of Musical Algorithms in Machine Listening and

Composition, in Digital da Vinci, pp. 127-157, Springer, 2013

Dubos, A., Frédéric Bevilacqua, Joseph Larralde, Joël Chevrier, Jean-François Jego. Designing Gestures for Interactive Systems: Towards Multicultural Perspectives. 16th IFIP Conference on Human-Computer Interaction (INTERACT), Sep 2017, Bombay, India. pp.524-526.

Echeveste, J., Cont, A., Giavitto, J.-L., Jaquemard, F. Operational semantics of a domain specific language for real time musician–computer interaction. J. of Discrete Event Dynamic Systems, 2013, vol. 23, n°4, pp 343-383.

Elgammal, A., Liu, B., Elhoseiny, M., Mazzone, M.: CAN: Creative adversarial networks generating "art" by learning about styles and deviating from style norms (2017). ArXiv:1706.07068v1

Esling, P., Chemla-Romeu-Santos, A., & Bitton, A. "Generative timbre spaces: regularizing variational auto-encoders with perceptual metrics". Proceedings of International DaFX conference, pp.23-27, Portugal (2018)

Esling, P. Chemla, A. Bitton, A. "Bridging audio analysis, perception and synthesis with perceptually-regularized variational timbre spaces", Proc. 19th International Society for Music Information Retrieval, vol. 1, Paris, France. AR: 23,2% Best paper award. (2018)

Fujie, S., Yagi, D., Matsusaka, Y., et al. Spoken dialogue system using prosody as para-linguistic information. In : Speech Prosody 2004, International Conference. 2004.

Fitch WT. Rhythmic cognition in humans and animals: distinguishing meter and pulse perception. Front Syst Neurosci. 2013;7:68.

François, A. R. J., Schankler, I., and Chew E., Mimi4x: An interactive audio-visual installation for high-level structural improvisation. International Journal of Arts and Technology, 6(2): 138–151, 2013.

François, A.R.J., E. Chew, D. Thurmond (2008). Visual Feedback in Performer-machine Interaction for Musical Improvisation. In Proc NIME, 277-280.

Gibson, W., The group ethic in the improvising jazz ensemble: A symbolic interactionist analysis of music, identity, and social context. Studies in Symbolic Interaction. 2010.

Gilhooly, K. J., Thinking: Directed, Undirected and Creative. London: Academic Press, 1996.

Giraud, M., R. Groult, E. Leguy, and F. Levé. 2015. "Computational fugue analysis." Computer Music Journal 39(2):77–96.

Goodfellow, I.J., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozairy, S., Courville, A., Bengio, Y., Generative adversarial nets (2014). ArXiv:1406.2661v1

Hadjeres, G., Pachet, F., Nielsen, F.: DeepBach: a steerable model for Bach chorales generation (2017). ArXiv:1612.01010v2

Herremans, D., Chuan, C.H., Chew, E.: A functional taxonomy of music generation systems. ACM Computing Surveys (CSUR) 50(5) (2017)

Hinton, G.E.: Boltzmann machine. Scholarpedia 2(5), 1668 (2007)

Kato, H., Ushiku, Y., Harada. T. Neural 3D Mesh Renderer. The 31th IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), 2018.

Ikei, Y, Hirota, K., Amemiya T., Kitazaki, M., Five Senses Theatre: A multisensory display for the bodily Ultra Reality, Emotional Engineering Vol.4, (Ed.) Shuichi Fukuda, Springer, 2016

Ishi, C. T., Ishiguro, H., et Hagita, N.. Analysis of relationship between head motion events and speech in dialogue conversations. Speech Communication, 2014, vol. 57, p. 233-243.

Kanehira, A., Takemoto, K., Inayoshi, S., Harada, T., Multimodal Explanations by Predicting Counterfactuality in Videos. The 32nd IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR), 2019.

Keil, Charles. The Theory of Participatory Discrepancies: a progress report. Ethnomusicology, 39(1), (1995) 1-19.

Kingma, D.P., Welling, M., An Introduction to Variational Autoencoders, arXiv:1906.02691, 2019

Kingma, D.P., Welling, M.: Auto-encoding variational Bayes (2014). ArXiv:1312.6114v10

Knapp, M., Hall, J., Nonverbal Communication in human interaction, Cengage Learning, 2013.

Kopp, S., Social resonance and embodied coordination in face-to-face conversation with artificial interlocutors. Speech Communication, 2010, vol. 52, no 6, p. 587-597.

Large, Edward W., and John F. Kolen. 1994. Resonance and the perception of musical meter. Connection Science 6(2–3):177–208.

Large, Edward W., and Caroline Palmer. 2002. Perceiving temporal regularity in music. Cognitive Science

26:1–37

Lartillot, O., Dubnov, S., **Assayag**, G., Bejerano, G., Automatic Modeling of Musical Style, International Computer Music Conference, La Havane, 2001, pp. 447-454

Lévy, B., Bloch, G., **Assayag**, G., « OMaxist Dialectics : capturing, Visualizing and Expanding Improvisations », NIME12, Ann Arbor, 2012, pp. 137-140

Lissek, H., Rivet, E., Laurence, T., Fleury, R., Toward Wideband Steerable Acoustic Metasurfaces with Arrays of Active Electroacoustic Resonators; Journal of Applied Physics. 2018.

McPherson, A.P. Kim, Y., Augmenting the Acoustic Piano with Electromagnetic String Actuation and Continuous Key Position Sensing. Proc. Intl. Conference on New Interfaces for Musical Expression NIME'10, 2010

Maniatakos, F., **Assayag**, G., Bevilacqua, F., Agon, C., On architecture and formalisms for computer assisted improvisation , Proc. Sound and Music Computing conference, SMC'10, Barcelona, 2010

Mehri, S., Kumar, K., Gulrajani, I., Kumar, R., Jain, S., Sotelo, J., Courville, A. & Bengio, Y. (2016). SampleRNN: An Unconditional End-to-End Neural Audio Generation Model (cite arxiv:1612.07837)

Meurisse, T., Mamou-Mani, A., Causse, R., Chomette, B., Sharp, D. Simulations of modal active control applied to the self-sustained oscillations of the clarinet. Acta Acustica, Hirzel Verlag, 2014, 100 (6),pp.1149-1161.

Meyer, L.B., Emotion and Meaning in Music. Chicago: Chicago University Press, 1956.

Moles, A., Théorie de l'information et perception esthétique, Flammarion, Paris, 1958

Moles, A., Art et ordinateur, Pris Casterman, 1971.

Monson, Ingrid. Saying something: jazz improvisation and interaction.University of Chicago Press, 1996.

Moreira, J., Roy, P., Pachet, F. VirtualBand: Interacting with Stylistically Consistent Agents.ISMIR, pages 341-346, Curitiba (Brazil), 2013

Mouawad, P., Dubnov, S., On Modeling Affect in Audio with Non-Linear Symbolic Dynamics, Advances in Science, Technology and Engineering Systems Journal, Vol. 2, No. 3, 1727-1740 2017

Mouawad, P., Dubnov, S., On Symbolic Dynamics and Recurrence Quantification Analysis for Affect Recognition invoice and Music, Perspectives in Nonlinear Dynamics 2016, Berlin

Nika, J., Chemillier, M., ImproteK, integrating harmonic controls into improvisation in the filiation of OMax, Proceedings of the International Computer Music Conference, pp. 180–187, 2012.

Nika, J., Chemillier, M., **Assayag**, G., ImproteK: introducing scenarios into human-computer music improvisation, ACM Computers in Entertainment, 14 : 2, article 4, 2017.

Nika, J., Deguernel, K., Chemla--Romeu-Santos, A., Vincent, E., **Assayag**, G., DYCI2 agents: merging the "free", "reactive", and "scenario-based" music generation paradigms, Proc. ICMC, Shangai, China, 2017

Novielli, N., De Rosis, F., and Mazzotta, I., User attitude towards an embodied conversational agent: Effects of the interaction mode. Journal of Pragmatics, 2010, vol. 42, no 9, p. 2385- 2397.

Ogawa, N., Y. Ban, S. Sakurai, T. Narumi, T. Tanikawa and M. Hirose: Metamorphosis Hand: Dynamically Transforming Hands, ACM Augmented Human 2016, 2016.

Pachet, F. and Roy, P. Markov constraints: steerable generation of Markov sequences. Constraints, 16(2):148-172, March 2011

Pachet, F., Musical virtuosity and creativity. Computers & Creativity, 2012.

Patel, Aniruddh D., John R. Iversen, Micah R. Bregman, Irena Schulz, and Charles Schulz. 2008. Investigating the human-specificity of synchronization to music. Proc.10th Intl. Conf. on Music Perception and Cognition 1–5, 2008.

Pinch, T., Trocco, F. Analog days: The invention and impact of the Moog synthesizer. Cambridge, MA: Harvard University Press, 2002.

Potter, K., Wiggins, G., and Pearce, M., Towards greater objectivity in music theory: Information-dynamic analysis of minimalist music. In Musicae Scientiae 11(2), 295-322, 2007

Pressing, J., Cognitive processes in improvisation. Advances in Psychology, Vol. 19, pp. 345–363, 1984.

Rabinovich, M.I, and Varona, P., (2016), Consciousness and joint Human-Robot Creativity; Chaotic Chunking, Frontiers Neuroscience 2016

Rabinovich, M., Trisan I., and Dubnov, S., Nonlinear dynamics of human creativity, IEEE International Conference on Systems, Man and Cybernetics, 2014

Roberts, A., Engel, J., Raffel, C., Hawthorne, C., Eck, D.: A hierarchical latent vector model for learning long-

term structure in music. In: Proceedings of the 35th International Conference on Machine Learning (ICML 2018). ACM, Montreal, PQ, Canada (2018)

Rowe, R., Machine Musicianship. MIT Press, Cambridge, MA, USA, 2004.

Rueda, C., **Assayag**, G., Dubnov, S., A Concurrent Constraints Factor Oracle Model for Music Improvisation », XXXII Conferencia Latinoamericana de Informática CLEI 2006, Santiago, 2006

Sanlaville, K., Assayag, G., Bevilacqua F., Pelachaud, C., Emergence of synchrony in an Adaptive Interaction Model, Intelligent Virtual Agents 2015 Doctoral Consortium, 2015, Delft,

Sawyer, R.K., Improvisational Cultures: Collaborative Emergence and Creativity in Improvisation, Mind, Culture, and Activity, 7:3, 2000

Schankler, I., Chew, E., and François A. R. J., Improvising with digital auto-scaffolding: How Mimi changes and enhances the creative process. In Digital Da Vinci, ed. Newton Lee, pp. 99–125. Berlin: Springer Verlag. 2014.

Scurto, H., Frédéric Bevilacqua. VIMOs: Enabling Expressive Mediation and Generation of Embodied Musical Interactions. 4th International Conference on Movement Computing, Jun 2017, London.

Smith, J., Chew, E., **Assayag** G., (Eds), Mathemusical Conversations : Mathematics and Computation in Music Performance and Composition, Feb 2015, Singapore. World Scientific; Imperial College Press, 2016.

Smith, J. B. L., Schankler, I., Chew, E., Listening as a Creative Act: Meaningful Differences in Structural Annotations of Improvised Performances. Music Theory Online, 20(3). 2014. www.mtosmt.org/issues/mto.14.20.3/mto.14.20.3.smith_schankler_chew.php

Steels, L. Evolving grounded communication for robots. Trends in cognitive sciences, 2003, vol. 7, no 7, p. 308-312.

Smith, J. B. L., Chuan, C., Chew, E., Audio Properties of Perceived Boundaries in Music. IEEE Transactions on Multimedia Special Issue on Music Data Mining, 16(5): 1219-1228, 2014.

Surges, G. and Dubnov, S. Feature Selection and Composition using PyOracle. Workshop on Musical Metacreation, Ninth AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment. Northeastern University, Boston, MA. October 14-15, 2013.

Thórisson, K. R. Natural turn-taking needs no manual: Computational theory and model, from perception to action. In : Multimodality in language and speech systems. Springer Netherlands, 2002. p. 173- 207.

Tokushige, H., T. Narumi, S. Ono, Y. Fuwamoto, T. Tanikawa, and M. Hirose: Trust lengthens decision time on unexpected recommendations in human-agent interaction, HAI2017, 2017.

Tokozume, Y., Ushiku, Y., Harada, T., Learning from Between-class Examples for Deep Sound Recognition. The 6th International Conference on Learning Representations (ICLR 2018), 2018

Tokozume, Y., Harada, T., Learning environmental sounds with end-to-end convolutional neural network. The 42nd IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2017), 2017

Toro M., Rueda, C., Agon, C., **Assayag**, G., GELISP: A Framework to represent musical constraint satisfaction problems and search strategies , Journal of Theoretical and Applied Information Technology, JATIT, 2016, 86 (2), pp.327-331.

Toro M., Rueda, C., Agon, C., **Assayag**, G., NTCCRT: A Concurrent Constraint Framework for Soft Real-Time Music Interaction, Journal of Theoretical and Applied Information Technology, JATIT, 2015, 82 (1), pp.184-193.

van den Oord, A., Dieleman, S., Zen, H., Simonyan, K., Vinyals, O., Graves, A., Kalchbrenner, N., Senior, A., Kavukcuoglu, K.: WaveNet: A generative model for raw audio (2016). ArXiv:1609.03499v2

Wang, C., and Dubnov, S., Pattern Discovery from Audio Recordings by Variable Markov Oracle: A Music Information Dynamics Approach, Proc. of 40th IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Brisbane, 2015

Wang C. and Dubnov, S., The Variable Markov Oracle: Algorithms for Human Gesture Applications, IEEE Multimedia, vol. 22, no. 4, pp. 52 – 67, 2015

Wang C., Hsu, J., and Dubnov, S., Machine Improvisation with Variable Markov Oracle: Toward Guided and Structured Improvisation, ACM Computers in Entertainment Journal, Second Special Issue on Music Meta-creation, 2016

Wiggins, G.A., Searching for computational creativity. New Generation Computing, 24(3):209–222, 2006.

Yang, L.C., Chou, S.Y., Yang, Y.H.: MidiNet: A convolutional generative adversarial network for symbolic-domain music generation. In: Proc. of the 18th International Society for Music Information Retrieval Conference (ISMIR 2017). Suzhou, China (2017)

Section b: Curriculum vitae

PERSONAL INFORMATION

Family name, First name: **Assayag, Gérard**, *Date of birth:* 20/06/1960, *Nationality:* French

*URL for web site:*repmus.ircam.fr/assayag

- **EDUCATION**

2009 **Habilitation** à diriger les recherches in Computer Science.
Université de Bordeaux II, Ecole doctorale de mathématique et d'informatique, France

1985 **Master** in Computer Science
Université Pierre et Marie Curie (UPMC), Paris

1977-1984 Undergraduate and graduate studies in Music, Musicology, Philosophy, Literature, Linguistics, Mathematics and Computer Science.

- **CURRENT POSITION(S)**

1992 – 2019 **Head of Music Representations** Research Group at **STMS** Lab (IRCAM, CNRS, Sorbonne University). Team's production : +50 PhD thesis, +100 Master thesis, + 150 Journal papers, 300 proceedings papers, + 100 books and chapters, 15 research awards

- **PREVIOUS POSITIONS**

2011 – 2017 **Head of the laboratory** Sciences and Technologies of Music and Sound (**STMS Lab**)
STMS is a 125 people joint lab co-operated by by IRCAM, CNRS, Sorbonne University

2003 – 2007 **Coordinator, ATIAM Master's program** (Acoustics, Signal Processing, Computer Science for Music), Sorbonne University and 4 partner universities.

1986 – 1992 **Free-lance consultant** R&D in digital intelligence systems for sound and music

1990-1991 **Professor of computer science** for Musical research and creation at IRCAM.

- **FELLOWSHIPS AND AWARDS**

2019 UCSD Distinguished Scholar grant recipient, invited researcher UCSD, San Diego, USA - JSPS grant recipient, invited researcher at Tokyo University Todai.

2018 Erasmus Mundus Team 2018 grant recipient, invited researcher at Tokyo University.

2007 Best Presentation Award, International Computer Music Conference 2007

2000 Winner Metro Company (RATP) Design Contest for the Centenary of the Parisian Metro

1981 Winner of the "Micro-Computer" and the "Art and the Computer" competitions launched by the French Government.

- **SUPERVISION OF GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS**

1992 – 2017 I have directly supervised 22 PhD, 23 Masters, 12 post-docs, at STMS Lab with Université Pierre et Marie Curie (UPMC), then Sorbonne University.

- **TEACHING ACTIVITIES (if applicable)**

1991 – 2007 Musical Informatics, Master ATIAM, Faculty of Engineeeing, Université Pierre et Marie Curie, IRCAM, — Computer Science for musicians, IRCAM

- **ORGANISATION OF SCIENTIFIC MEETINGS. Leading organiser of :**

2019 ImproTech Paris-Athina 2019, international workshop and festival on co-improvisation with Digital Intelligence, Athens, Greece, September 2019.

2017 Improtech Paris -Philly 2017, Philadelphia, Dec 2019.

2015 Mathemusical Conversations. International workshop, Institute for Mathematical Sciences, Singapour. Montreux Jazz Festival International Workshop : Musician and machine.

2014 ELS'14 - 7th European Lisp Symposium, IRCAM, Paris, France

2012 Improtech Paris -New-York 2012, New-York, May 2012.

2011 MCM 2011 International Conference on Mathematics and Computation in Music, IRCAM, Paris. Forum 2011 «Next Generation of Virtual Reality», Todai Tokyo University.

2009 International Symposium on Complexity in the arts and sciences, IRCAM, Centre Pompidou

2004 SMC 2004, First International Sound and Music Computing conference, IRCAM, France.
2000 MaMuPhi, monthly seminar in Mathématics, Music and Philosophy, Ircam, 2000/2001.`
1999 Forum Diderot Mathematics and Music, international workshop under the auspices of the European Mathematical Society.
1987 International Symposium on New Technologies for Music Printing, MIDEM, CANNES.

- **INSTITUTIONAL RESPONSIBILITIES (if applicable)**

2019 Member of the HCERES (High Authority for Research Structures Evaluation) evaluation expert board, founding member Sorbonne Center for Artificial Intelligence (SCAI)
2011-2019 Member of Sorbonne Université (SU) Doctorate School selection committee for PhD Grants
2015-2017 Founding Member : Collegium Musicae research Institute, Sorbonne Université,
2011-2017 Head STMS Lab, IRCAM, CNRS, Sorbonne University, Member of the council and bureau of SU doctoral school, Member of the Scientific Council, Faculty of Engineering, SU.
2013 Member of the Evaluation Expert Board, Agence Nationale de la Recherche (ANR), program "Contenu et Interaction" 2010-2013
2012 Member of the Experts Committee, evaluation of European Project Integra II, Fusing Music and technology, EU Culture Program
2003-2007 Head ATIAM Master's Program, Pierre et Marie Curie University

- **MEMBERSHIPS OF SCIENTIFIC SOCIETIES (if applicable)**

Founding Member, Society for Mathematics and Computation in Music, Founding Member, French Society for Musical Informatics, Member FWO Research Society on Foundations of Music Research.

- **MAJOR COLLABORATIONS (if applicable)**

Shlomo Dubnov, CREL Lab, UCSD, USA, Marc Chemillier, CAMS Lab, EHESS, France, Elaine Chew, C4DM Lab, Queen Mary, U.K., Philippe Codognet, Japan-French Lab of Informatics, Tokyo U., Japan, Adrien Mamou-Mani, Hyvibe Sound Tech Startup Company, Tatsuya Harada, AI Lab, Tokyo U.

- **RESEARCH CONTRACTS**

2020-2022 MERCI, National Research Agency (ANR) Grant, AI creative agents, Mixed Reality, PI.
2018-2025 ACTOR**,** SSHRC/NSERC Partnership Grant, Timbre and Orchestration Modeling
2018-2021 TENOR, Canadian SSHRC Partnership Development Grant, Music Notation and Digital Intelligence
2017-2020 MAKIMOno, ANR international France/Canada Grant, Multivariate Analysis and Knowledge Inference for Musical Orchestration
2014-2018 DYCI2, ANR Grant, Dynamics of Creative Improvised Interactions, PI
2013-2017 EFFICACE, ANR Grant, Dynamic Time Structures in Comp. Assist. Composition.
2009-2013 IMPROTECH, ANR Grant. Improvisation and Machines.
2012-2015 INEDIT ANR, Grant. Composing Interaction and Time.
2010-2013 SAMPLE ORCHESTRATOR 2, ANR Grant, New generation orchestration
2010-2013 CREMUSCULT, ANR grant, Modeling Music Creativity and Cultural Impact
2010-2013. REACT+, Colombia COLCIENCIAS Grant, Concurrent Constraint Programming
2007-2010 SAMPLE ORCHESTRATOR, ANR Grant, New generation sampling
2001-2003 CUIDADO, IST European Project, 5th PCRD, Music Information Retrieval

- **PATENTS**

1998 Process for **sympathetic resonances** on digital piano, Inventors: G. Assayag, G. Bloch

- **LEADERSHIP / selected examples of young scientists advancement**

Some former PhD students and post-docs trained by G. Assayag have become : Professor (Sorbonne U., C. Agon, U. of Brisbane A. Brown, U. of Cali, G.Sarria, U. of Nantes, C. Truchet, U. of Oslo, O. Lartillot, U. Santa Cruz, P. Nauert), Researcher at Sony Computer Science Lab (P. Hanappe), award-winning musician (G. Nouno, J. Blondeau, L. Morciano, L. Rokita, F. Avitabile, D. Ghisi), CEO in high-tech companies (A. Cont, F. Maniatakos, B. Zamborlin, C. Laurier); Computer Music Designers (B. Lévy, B. Meudic); industry executives (O. Delerue, G. Carpentier)

Appendix: All ongoing and submitted grants and funding of the PI (Funding ID)

On-going Grants (Please indicate "No funding" when applicable):

Project Title	*Funding source*	*Amount (Euros)*	*Period*	*Role of the PI*	*Relation to current ERC proposal*[2]
MERCI	ANR	600K€	2020-2022	PI	MERCI is mainly focused on industrial collaboration and transfert of music software technologies, a different focus from REACH
ACTOR	SSHRC	1679K€	2018-2025	Expert	This project with 18 international partners focuses on assisted Classical Orchestration, a different focus from REACH
TENOR	SSHRC	24K€	2018-2021	Expert	TENOR concerns music notation with no overlap with REACH.
Makimono	ANR	500K€	2017-2021	Expert	As a difference with REACH, this project is highly focused on data science tools for orchestration and composition

Grant applications (Please indicate "No funding" when applicable):

Project Title	*Funding source*	*Amount (Euros)*	*Period*	*Role of the PI*	*Relation to current ERC proposal*[2]
DemoCreaCy	ANR	488K€	2020-2023	Chair	DemoCreacy is a university chair oriented toward AI education and teaching, a different focus from REACH

Section c: Ten years track-record

Gérard Assayag, an **IRCAM senior researcher**, has founded and currently heads the **Music Representation team** (RepMus) in the STMS Lab. STMS (Sciences and Technologies of Music and Sound) is a joint research unit co-operated by IRCAM, CNRS (Centre National de la Recherche Scientifique) and Sorbonne University. IRCAM (Institut de recherche et de coordination acoustique / musique) created by famous conductor and composer Pierre Boulez is the world's largest institution dedicated to both music creation and sound/music scientific research. Assayag has been the **Head of STMS Lab** from 2011 to 2017 and, as such, involved in national and international research policies in Computational and Human Music Sciences, with a population of 125 people (researchers, engineers, techs, admin and PhD students) in his jurisdiction.

Assayag is a **co-founder of Collegium Musicae**, the Sorbonne University Institute for Music Sciences ; he has been instrumental in the recent creation of the **Sorbonne Institute for Artificial Intelligence** (SCAI) where he has conceived the Digital Humanity Axis programme. He has co-founded the **French Society for Computer Music (AFIM)**, the international learned **Society for Mathematics and Computation in Music** (SMCM) and its associated first-of-kind peer-reviewed **Journal of Mathematics and Music** (JMM), now a pillar of the research community in music computing.

Assayag's **personal researc**hes (involving supervision of 22 PhD and 23 Masters works) and **team direction** (encompassing over 50 PhD works and 100 Masters) has resulted in several **flagship technologies** covering Computer Assisted Composition, Orchestration or Improvisation, (OpenMusic: +100,000 downloads, OMax / Dyci2: + 100 concerts on international scenes and festival including Montreux Jazz Festival or Paris Centre Pompidou, interaction with legendary musicians including David Bowie's companion pianist Mike Garson or contemporary jazz headliners Steve Coleman and Steve Lehman).

Assayag has shown **strong leadership** in the training and advancement of young scientists. The students and young researchers he has supervised have become professors in universities throughout the world, head of high-tech companies or industry executives, award winning musicians (see CV). As **head of the pluri-disciplinary ATIAM masters**, G. Assayag has defined its pedagogical program in the frame of the "Bologna Process" to ensure world-wide comparability in the standards and quality of higher-education qualifications. **More than 150 ATIAM students have since engaged in a PhD**, of which the greatest part have thereafter become university professors, researchers, industry executives or high-tech startup leaders all around Europe.

Assayag has defined through theoretical publications and popular technologies the concept of **symbolic interaction** to account for rich and versatile musical dialog between machines and humans, traversing several levels and scales of information, from acoustic signal to higher symbolic and cognitive structures. This concept is now evolving towards general co-creativity in cyber-human workship, a central theme of this project.

Selected Publications

Déguernel, K., Vincent, E., Assayag, G., Probabilistic Factor Oracles for Multidimensional Machine Improvisation. Computer Music Journal, 42:2, article 4, 2018

Nika, J., Chemillier, M., Assayag, G., ImproteK: introducing scenarios into human-computer music improvisation, ACM Computers in Entertainment, 14 : 2, article 4, 2017.

Assayag, G., Improvising in Creative Symbolic Interaction. In Smith; Chew; Assayag (Eds), Mathematical Conversations: Mathematics and Computation in Music Performance and Composition, World Scientific; Imperial College Press, pp.61 - 74, 2016

Smith, J., Chew, E., Assayag, G., (Eds), Mathemusical Conversations : Mathematics and Computation in Music Performance and Composition. World Scientific; Imperial College Press, 2016.

Assayag, G. Creative Symbolic Interaction, 40th Intl. Comp. Mus. Conf. and 11th Sound and Music Computing Conf. (ICMC / SMC joint conf.), Athenes, Greece, pp 1-6, 2014.

Dubnov, S., Assayag, G., Music Design with Audio Oracle using Information Rate. First International Workshop On Musical Metacreation (Mume 2012), Oct 2012, Palo Alto, United States. pp.1-1, 2012.

Cont, A., Dubnov, S., Assayag, G., On the Information Geometry of Audio Streams with Applications to Similarity Computing, IEEE Trans. on Audio, Speech and Language Processing, 19 (4), pp.837-846, 2011

Dubnov, S., Assayag, G., Cont, A., Audio Oracle Analysis of Musical Information Rate, Proceedings of IEEE Semantic Computing Conference (ICSC2011), United States. pp.567—571, 2011

Assayag, G., Bloch, G., Cont, A., Dubnov, S., Interaction with Machine Improvisation, in S.Argamon, S. Dubnov and K.Burns (Eds) The Structure of Style: Algorithmic Approaches to Understanding Manner and Meaning, 2010, Springer, pp.219-245

Assayag, G., Gerzso, A., New Computational Paradigms for Computer Music , Delatour, Paris, 2009

Selected Invitations

G. Assayag has delivered invited talks (distinguished scholar) or keynote-talks at :

Collège de France, Ecole Normale Supérieure, Radcliffe Institute Harvard, Ecole Polytechnique, Ecole Centrale, Ecole des Mines, Centre Pompidou, Boston University, U.C. San Diego, U. of Southern California, U.C. Santa Barbara, CIRMMT Mc Gill U., Todai U. Tokyo, Geidai U. Tokyo, Tohoku U. Sendai, U. of Campinas, NYU Abu Dhabi, Montreux Jazz Festival, Onassis Cultural Center Athens, Pontificiad Javeriana Universidad de Cali, Queen Mary U., U. of Athens, Institute for Mathematical Sciences NUS Singapore, Lorentz Center Leiden, International Computer Music Conference, Sound and Music Computing, European Lisp Symposium Madrid, Intl. Conf. on Inf. Elect. Systems Sendai, U. Pompeu Fabra Barcelona, University of Minnesota, Calit2 Institute UCSD, Tokyo NTT InterCommunication Center.

Board Memberships

G. Assayag serves or has served recently on:

Advisory Board of the Springer book series Computational Music Science, Editorial board of Journal of Mathematics and Music *: Mathematical and Computational Approaches to Music Theory, Analysis, Composition and Performance* (founding member), board of Society for Mathematics and Computation in Music (founding member), Editorial Board of the Journal of New Music Research, board of directors of the French Musical Informatics Association (founding member), executive board of Sorbonne Collegium Musicae (founding member), scientific advisor board Sorbonne Center for Artificial Intelligence, reviewing board of HCERES (National High Authority for Research Structures Evaluation), Scientific Council of Sorbonne University Science Faculty, Executive Board of Sorbonne University Doctoral School EDITE, reviewing board of EU Culture Program, reviewing Board of Agence Nationale de la Recherche (ANR)

Conference organization

G. Assayag has been a leading organizer of international workshops or symposia :

ImproTech Paris-Athina 2019, international workshop / festival on cyber-human co-improvisation, Athens Sep 2019 ; Improtech Paris-Philly 2017, Philadelphia, Dec 2019 ; Mathemusical Conversations Intl. Workshop, Inst. for Math. Sciences, NUS Singapore, Jan 2015 ; Montreux Jazz Festival Intl. Workshop : Musician and machine, Jul. 2015, ELS'14 - 7th European Lisp Symposium, IRCAM, Paris, 2014 ; Improtech Paris -New-York 2012, New-York, May 2012 ; MCM 2011 Intl. Conf. on Mathematics and Computation in Music, IRCAM, Paris 2012; Forum 2011 «Next Generation of Virtual Reality», at Tokyo and Tohoku University ; International Symposium on Complexity in the arts and sciences, IRCAM, Centre Pompidou, 2009.

Creative activity

G. Assayag has performed a great amount of concerts in high visibility venues, with world class performers, using or demonstrating the results of his researches in computational co-creativity including :

The Loft, UCSD, Uzeste Music Festival, Annenberg Center Philadelphia, Centre Georges Pompidou Paris, IRCAM, Collège de France l, Montreux Jazz Festival, Singapore Yong Siew Toh concert Hall, New York University @ Abu Dhabi Concert Hall, Cité des sciences et de l'industrie Paris, Béla Bartók National Concert Hall Budapest, The Roulette Brooklyn, Conservatoire de Paris, Musée des confluences Bordeaux, Hexagone Concert Hall Meylan, Music Instruments Museum Berlin, Molière Concert Hall Bordeaux, Le Rocher Palmer Concert Hall Bordeaux.