MERCI

Mixed Musical Reality with Creative Instruments

Réalité Musicale Mixte avec Instruments Créatifs

Summary table of persons involved in the project:

Partner	Name	First name	Current position	Role & responsibilities	Involvement Personal	Involvement Partner
IRCAM (STMS Lab)	**Assayag**	**Gérard**	Research Director	**Project Leader, Coordinator WP CO and CA**	*15*	71 p. month
	Esling	Philippe	Lecturer,	Creative Artificial Intelligence, coordinator WP DD	*10*	
	Bresson	Jean	Researcher	Musical Informatics research, WP CA & DD	*10*	
	To recruit		*post-doc*	*Creative agents model and architecture, WP CA & HA*	*24*	
	To recruit		*post-doc*	*Creative AI orchestration and generation, WP DD &*	*12*	
EHESS (CAMS Lab)	**Chemillier**	**Marc**	Research Director	**PI, coordinator WP AK and ED**	*24*	51 p. month
	André	Julien	PhD candidate	Social science field experiment and modelling, WP AK	*3*	
	To recruit		*post-doc*	*Improvisation and synchronisation, WP AK & CA*	*24*	
HyVibe	**Mamou-Mani**	**Adrien**	CEO (PhD)	**PI, coordinator WP HA**	*7*	45 p.month
	Beaulier	François	CTO (PhD)	R&D Creative Instrument, WP HA	*10*	
	Volsky	Matthew	Head Marketing	Dissemination Creative Instrument, WP HA	*4*	
	To recruit		*Engineer*	*Development Creative Instrument WP HA & CA*	*24*	
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I. Context, positioning and objectives

a. Objectives and research hypothesis

Context and general goal

Improvisation can be seen as a major driving force in human interactions, strategic in every aspect of communication and action. In its highest form, improvisation is a mixture of structured, planned, directed action, and of hardly predictable local decisions and deviations optimizing adaption to the context, expressing in a unique way the creative self, and stimulating the coordination and cooperation between agents. An invaluable observation deck for understanding, modeling and promoting co-creativity in a context of distributed intelligence, Improvisation is an indispensable ability that any cyber-human system should indeed cope with in an expert way. Improvisation is instantiated in its most refined form in music, where the strongest constraints govern the elaboration of highly complex multi-dimensional, multi-scale, multi-agent actions in a cooperative and timely fashion so as to achieve creative social and cultural cooperation.

Setting up powerful and realistic human-machine environments for improvisation necessitates to go beyond the mere software engineering of creative agents with audio-signal listening and generating capabilities, such as what has been mostly done until now. The partners, Ircam STMS Lab, EHESS Cams Lab, and HyVibe startup company propose to drastically renew the paradigm of human-machine improvised interaction by bridging the gap between the computing logics of co-creative musical agents and mixed reality setups anchored in the physics of acoustic instruments**.** In such setups of "physical interreality" (a mixed reality scheme where the physical world is actively modified by human action), the human subjects will be immersed and engaged in tangible actions where full embodiment in the digital, the physical and the social world will take place thanks to a joint effort gathering experts from a large inter-disciplinary spectrum.

The main objective of this project is to create the scientific and technological conditions for mixed reality musical systems, enabling human-machine improvised interactions, based on the interrelation of creative digital agents and active acoustic control in musical instruments. We call such mixed reality devices *Creative Instruments*.

Functionally integrating creative artificial intelligence and active control of acoustics into the organological heart of the musical instrument, in order to foster plausible physical interreality situations, necessitates the synergy of highly interdisciplinary public and private research, such as brought by the partners. Such progress will be likely to disrupt artistic and social practices, eventually impacting music industry as well as amateur and professional music practices in a powerful way.

Positioning and scope

Whether in art, education, or industry, we are facing a new era of continuum between human creativity and autonomous information processing capabilities of physical objects that turn joint human machine interaction into an augmented and mixed reality. Co-creativity between humans and machines brings about the emergence of complex distributed information structures, such as in networked ambient intelligence or augmented performances of groups of musical agents. With technologies allowing us to extract new features from physical (e.g. acoustics, visual) and human (e.g. body, languages) signals, combined with novel generative learning of space-time-frequency signal representations, we face the complexity of fluid protocols of communication, interaction, cooperation, synergy or conflict in cyber-human networks. These new cooperative micro-societies need fresh conceptual and technological frames in order to be fully understood. This project aims at bringing a serious contribution to this field in the musical domain, through instrumental mixed reality allowing musicians of any level of skill and training to experiment enhanced individual creative experience, to connect to wide data and computing resources, or to link to communities of fellow artists or artificial agents.

The musical market has recently introduced augmented instruments such as the HyVibe Guitar created by one of the partners, the Yamaha Transacoustic instruments, or the Magnetic Resonator piano designed by Andrew McPherson (McPherson 2010). These devices generally feature embedded active acoustic control for audio quality enhancement and sound effects generation, generally in the form of an integrated mechatronics system, acting directly on the mechanics of the instrument and sensing its physical dynamics. These so-called *SmartInstruments* are a first step toward the fusion of sophisticated information processing power down to the core physics of musical devices, in order to enhance their interaction capabilities. However, at this stage, these systems do not show any substantial musical creativity, lacking *machine musicianship* (the capacity to smartly process music information at a structural, symbolic level), high level *interaction strategies* or *generative autonomy*.

The purpose of this project is to **create the scientific and technological context such that *Smart Instruments* may fully become *Creative Instruments*** by embedding artificial musical intelligence, machine musicianship and powerful interaction skills, in a seamless integration with the underlying acoustic and mechatronics devices. A Creative Instrument will be able to listen continuously to the performance of the musician playing it, in order to figure out his/her musical directions, and to dialogue creatively with him/her in an unheard experience of mixed musical reality where the sounds produced by the performer and the ones created artificially will blend in a meaningful musical polyphony. This mixed musical reality will unfold in the melodic, harmonic, rhythmic, orchestral dimensions of music, featuring a creative musical companion seated at the very heart of the instrument and acting as an artistic avatar, an assistant to creation, a fellow performer, an incentive to learning, practicing and communicating in the musical language.

More broadly, progresses in solving the question of cyber-human improvised musical interactions, whether using solely software agents or physical augmentation, are a precious start to move forward in the direction of modelling improvised interactions in general. We thus consider musical improvisation as a central field of study in this project and as a springboard towards generalized human and cyber-human creative synergies. For this reason, it is of the essence to found our technological approach on a broad understanding of the mechanisms of improvisation through the lenses of human and social sciences as well, in particular on anthropology of improvised practices and knowledges. This opening will be essential in order to be able to observe, analyze, understand and collect behavioral data on improvised interaction between humans as well as between humans and cyber-entities, as a precious intake for feeding the models at work in the project.

Improvised creative interactions between humans and machines can thus be studied from different perspectives (social sciences, AI, signal processing, control theory, robotics) and modalities in order to highlight the conditions under which these interactions can emerge, their temporal adaptation dynamics, their strategies, and to exploit their creative potential. We have coined the expression *co-creativity* between human and artificial agents in order to emphasize the fact that creativity in that case is an emerging phenomenon resulting from complex interactions and crossed feed-backs between actors, and cannot be reduced to one or the other agent's production in isolation, whether the latter be human or artificial. This is an important notion in our project as it neutralizes the endless philosophical question of whether artificial entities can be qualified as "creative" or not, and shifts the research interest to the exploration of how to build the best possible technical tools in order to allow co-creative interaction to occur. As part of this project, we propose to make a decisive move, by rooting cyber-human co-creativity into the physical realm of Creative Instruments interreality.

Research Questions and Difficulties

Beyond known cyber-physical systems that create a continuity between the digital and the physical world, *Creative Instruments* constitute a *cyber-human* experience by bridging human and computational creativity through the mediation of a combination of material tools such as augmented acoustic instruments and of digital ones such as generative learning and artificial intelligence .

The research ecosystem to be put in place needs us to collaboratively answer a series of research questions :

- How to augment the expertise of digital agents with enhanced computational creativity and connectivity so they can enter into a more convincing interplay and co-creativity with humans
- How to augment the capacities of digital agents with physical extensions into acoustic musical instruments, so they can foster embodied interactions with humans
- How to augment the human possibilities by interfacing them into mixed reality set-ups anchored in musical instruments with creative agents so they can boost their individual and relational creative potential.

These questions are essential for computers to be able to process in real time the complex multi-variate time signals exchanged by humans and cyber-entities. These signals — especially in the case of music — carry implicit multidimensional and multi-scale semantic structures that are difficult to delimit correctly and efficiently, but are nevertheless paramount to the proper functioning of artificial perception and music generativity. Another difficulty lies in the gathering of these functionalities into a single object, the musical instrument, a device emblematic of the highly creative and aesthetic relationship between human sensory-motor system, memory, imagination and intentionality. We will pay great attention to careful design of the system's musical functionalities and of the perception / action loop it supports, so as to regulate the appropriate feed-back processes between the human performer, the physical mechatronics and the creative software agents, triggering in return productive cross-learning mechanisms. In order to fully understand these issues in the context of human practices, we will also enforce the study of the power of such instruments as driving forces in the process of knowledge acquisition and music creation, considering the social traces left in the process of their appropriation and sharing and the affordances that shape their usage. This dimension of the project related to instrumentality, embodiment and interfaces will require expertise from the social science domain as provided by the CAMS.

Expected results

One of the practical output of the project will be the realization of the first concrete prototype of Creative Instrument based on the HyVibe Guitar, by expanding it with mixed reality and interreality features and by equipping it with creative digital agents , as a prelude to extension to other instrument families. Novel applications for interacting with human musicians will be implemented in the instrument and evaluated, such as : creative backing tracks — adding versatile accompaniment in constrained styles; creative co-improvisation — where the instrument freely creates autonomous content or doubles the musician's playing with ever changing and coordinated musical lines; creative looper — with record/loop processes which evolve by themselves to new generative contents; creative orchestration — blending in sophisticated arrangements and orchestrations. These are only a few examples of how the Creative Instrument will potentially bring about the long-awaited convergence between physicality, information processing and creativity, in a manner that will be maneuvrable and enjoyable by all, at all levels of skills and expertise.

In addition to instrument prototypes, the project will provide theoretical foundations, technologies, software suites and experimental data made available in open-access to the research community as well as to other communities (e.g. augmented instrument design). These products will be the result of confronting several scientific challenges, including: creation of a model of knowledge and decision making for synchronous and asynchronous interaction strategies of agents involved in individual and collective improvised interactions ; augmentation of human abilities through mixed reality instrumental setups with embedded creative artificial intelligence ; improvised behaviours observation and human data collecting and sharing. In the course of this project, we wish to finally understand better the processes of cyber-human co-creativity , enrich the users' perceptual, emotional and social experience and energize their individual or collective experience of improvisation.

b. Position of the project and state of the art

Originality and novelty of the proposal

This project is the first attempt to our knowledge to build a coherent scientific and technological body of work around the idea of computational co-creativity through interreal immersion of musicians using their own acoustic instrument. While we believe this will open up a whole new world of practices, artistic creations, pedagogical experiences, derived technologies and social relations in the realm of music, the project will also bring generic methods applicable to other domains such as : interactive and generative machine learning as an alternative to supervised methods when data is versatile and rare; stylistic modelling as construction tool for shaping artificial individualities; temporal adaptation of interaction as self-organised cyber-human strategies; information dynamics as cognition models of prediction and anticipation; deep-learning multimodal embedding spaces as general representations blending learning , interaction and creativity so that each feeds the other. This project thus adopts a genuinely interdisciplinary approach linking music studies, human and social sciences, artificial intelligence, signal processing, acoustics and automation in order to better ascertain the conditions of cyber-human co-creativity and deliver unheard musical tools for enhancing human artistic development potential.

State of the art and contributions by the partners

The vision of computational co-creativity we promote in this project also occupies an original spot with respect to the international heavy-weighted competitors such as Google Magenta, Sony Flow Machines, MIT Media-Lab or Spotify, by offering a singular coupling of fluid interaction based on improvisation, creative artificial intelligence (Esling 2018), mixed reality setup and social science assessment (Chemillier & al 2016), with potential outputs in academic research, educational and creative technologies, as well as in industry.

As a precursor to most recent studies on computational creativity, interactive musical generativity has been addressed through such topics as algorithms and computer architectures (Blackwell 2012), dynamics of interactions seen as a complex system (Canonne 2011) or synchronization and matching of audio descriptors between live play and stored model (Moreira 2013). Assayag, Dubnov and Chemillier 's seminal work in style modelling have led to the OMax improvisation paradigm using a formal construction called the Factor Oracle (Levy & al 2012), and recently actualized with a series of work combining the Oracle with a Bayesian framework (Deguernel & al 2018) or scenario planification and pulse-based improvisation (Nika & al 2017). OMax (with its siblings softwares SoMax, ImproteK and Djazz) is now an internationally praised reference in the field of live improvisation with more than 100 concerts, workshops and master classes all around the world and renown musicians playing with it. Form analysis is a major topic in Music Information Retrieval and is useful in the listening components of such improvisation systems. It has been studied with methods from different fields. (Giraud et al. 2015) used dynamic programming to perform fugue analysis by detecting the occurrences of each motif. A similar method was used for sonata form analysis by (Bigo et al. 2017). (Bimbot et al. 2016) introduced the System & Contrast model where the general structure of a musical segment is divided recursively in contrasting morphological elements living on a polytope geometrical model. Wang and Dubnov have introduced methods from nonlinear dynamics and variable markov oracle (VMO) that reduce a multivariate time series down to a symbolic sequence while detecting recurrences of sub-sequences of variable length (Wang and Dubnov, 2015).

On the physical side, the guitar *SmartInstrument* resulting from the ANR IMAREV research (PI : A. Mamou-Mani) and commercialized by HyVibe, has brought embedded computing, mechatronics and physical modelling straight to the fingers of the musician (Meurisse & al 2014, Benacchio & al 2012). It is the very first of its kind, even if active instrumental acoustics experiments have indeed been carried out in several labs such as the ExCITe Center at Drexel University (McPherson 2010), or EPFL acoustics lab (Lissek 2018), and of course at Ircam (augmented violin, clarinet, string quartet). HyVibe's technology combines sensors, multiple actuators, integrated algorithms, control interface, and a printed circuit board designed to be the fastest sound card in the world. The very low latency system permits to control feedback and transform the guitar's natural vibrations from the soundboard, via the bridge where the instrument performs best.

Physical SmartInstrument (Benacchio 2016) and Creative Agents for Improvisation systems such as Omax (Assayag 2016), have already been the subject of successful collaborative research involving the partners, either individually or in combination (ANR projects : ImproTech 2009, Sample Orchestrator 2 2010, IMAREV 2011, EFFICACe 2013, DYCI2 2014), yielding several academic awards for young researchers and broad international dissemination and recognition.

On the social science side, the types of improvisation addressed in this project belong to one of the two categories defined in (Bailey 1999) as idiomatic and non-idiomatic, which roughly correspond to regular pulse-based improvisation and free improvisation. The term "idiom" used by Bailey highlights the existence of a cultural context and a community of people sharing this idiom as they could share a language. This raises the question of taking into account a particular social and cultural context in the evaluation of improvisation agents, as well as evaluating the integration of digital or mixed reality devices such as Creative Instrument in live performances — possibly modifying the artist's and audience's relationships and disrupting their perceptual and emotional patterns. The study of technology in musical performances lies at the crossroad between performance studies (Auslander 1999) and sound studies (Pinch & Trocco 2002) as in Butler's in-depth work on DJ and laptop live improvisation practices (Butler 2014) mainly devoted to the specific context of electronic dance music although this style of music serves as an exemplary instance of trends that are present to varying degrees in almost all music today. On a more conventional music instrument side, improvisation has been studied in the reference works on jazz interaction (Monson 1996, Berliner 1994). Concerning pulse-based improvisation, a more specific problem arose from the studies on micro-timing and there exists an active research field dealing with the study of rhythmic interaction between musicians in the context of jazz improvisation. The notion of participatory discrepancies introduced in (Keil 1995) has paved the way to a study of timing in jazz at a micro level. The pioneering analysis developed in (Cholakis 1995) has been followed by researches involving measurement of timing in musical performances (Doffman 2008) leading to the introduction of a model of entrainment that describes rhythmic interaction between musicians as the coupling of autonomous oscillators (Clayton 2012). This subject is also connected to technological issues through the particular domain of score following (Echeveste et al. 2013) which is directly related to the works on the improvisation softwares OMax, ImproteK and Djazz by Assayag, Chemillier and Dubnov.

Preliminary results

The partners have already developed over the years two platforms in the domains of augmented musical instruments and creative agents.

The first platform developed by HyVibe, *SmartInstrument*, is cyber-physical in nature providing a combination of acoustic instrument, mechatronics, digital audio software, and control / interface system implanted directly on-instrument or in mobile devices such as smartphones. It fills a continuous path between capture of the physical signals, physical modeling, signal processing, and mechanical actuation back in the material world. This achievement follows fundamental research work led by Adrien Mamou-Mani at Ircam in the ANR IMAREV project (Active Music Instruments with Virtual Settings) and prolongated in HyVibe. IMAREV has brought prototype instruments (guitar, violin, clarinet, percussions) whose vibration properties and acoustic sound qualities can be modified on the fly thanks to embedded active acoustic control. An onboard Active Vibration Control module (COALA) with extremely low i/o latency (less than 10 microseconds) allowed experimental development of control algorithms (modal control, adaptive filtering, phase inversion), with piezoelectric or electromagnetic sensors at the input and electrodynamic actuators at the output. From this platform a number of *SmartInstruments* have been built with a control loop allowing to manipulate the sound

(sound quality improvements, digital audio effects such as reverberation, filtering, distortion, timbre modulations) directly at the instrumental source while preserving the acoustic radiation and mechanical behavior of the instrument.

The second platform born in the Ircam Musical Representations team is cyber-human in nature and focuses on the creative dynamics of improvised interaction between human musicians and AI-based creative agents, as a result of ANR DYCI2 project (PI G. Assayag). It provides computational creativity tools who nourish, enrich, stimulate human creativity in a human-machine improvised interaction situation. The preliminary results take the form of a large open source software suite in Python, Dyci2Lib, freely available to the research community, comprising of a collection of artificial listening models, statistical sequence models, generative heuristics, time management strategies, and basic real-time architectures of interactive agents.

The existence of these preliminary works reduces significantly the risks inherent to this new research and will make success within reasonable reach by providing an important set of intellectual and technological assets to start with.

The Hyvibe Guitar control panel

(www.youtube.com/watch?v=xHyJiJQKGD0)

Early SmartInstrument violin prototype at Ircam

c. Methodology and risk management

Methodology

Considering the research context and preliminary results, we wish to optimize research productivity and risk containment by operating simultaneously in two symmetrical and converging directions which will eventually join in the inception of the Creative Instrument.

a. **Augment the cyber entities abilities** with enhanced computational creativity, autonomy and multimodal sensitivity to context, as well as with cyber-physical actuation inside the instrument, so they can enter into a convincing expert interplay with humans operating the musical instrument.

b. **Augment the human abilities** by interfacing them into mixed reality by the mean of embodied instrumental interfaces which will augment their musical awareness and efficiency, so they can interact in a natural and creative way with artificial agents.

The articulation of these two approaches through a series of research / development cycles fed by a series of more fundamental research tasks, providing the necessary modelling tools and social science assessment and data, will lay the research eco-system ground in order to aim at the realization of the first prototypes of Creative Instrument. In order to coordinate this multi-disciplinary approach in time, we will launch two clusters of research work packages which will interact throughout the duration of the project:

1. **Modelling tools and human data providers —** machine learning research providing trained models, and social science field research providing human data and heuristic guides for model parametrization.
2. **Technological tools and prototypes providers** —develop experimental platforms for mixed reality and computational creativity software, joining together the two augmentations (a) and (b) in Creative Instrument prototypes.

These two clusters will be complemented and articulated by (3) an **Experimentation, Usage and outreach package** impulsing the timing of a series of iteration between modelling, prototyping and experimentation tasks. Going through fast research and development cycles favoring interaction between all work packages, with milestone deliverables produced at the end of each yearly cycle, will smooth-out the interdisciplinary cooperation and prevent unforeseen problems that could potentially seize up the organization of the project. The Work Plan subsection below details this program's precise package and sub-task breakdown.

Inside this program, we will jointly use methods drawn from (1) Interactive computational creativity, (2) active acoustic control of music instruments (3) machine learning and data-science of musical information, and (4) social sciences and anthropology of improvised practices.

Computational creativity and acoustic control will be based on the reliable methodology underpinning the two platforms presented in the Preliminary results section, with enhancements defined by the two augmentations presented in (a) and (b).

Machine Learning of complex multi-variate signals such as musical signals, involving structure and knowledge discovery (Esling 2018), will be mandatory to understand and process, mostly in real time, the complex temporal signals exchanged by humans and cyber-entities such as creative software agents. These signals bear implicit multi-dimensional and multi-scale semantic structure that is very difficult to delineate, but that is nonetheless necessary for machine perception and learning to work properly.

The Social Science, anthropological expertise in improvisational practices and knowledges will be essential in order to observe, archive and understand collective improvisation between humans as well as between humans and computers, in order to guide the conception of the perceptual, generative and interaction models. These studies at the interface of technology and artistic practices will proceed on live performance integrating artifacts, involving different modes of human-machine interaction, in diverse cultural background. They 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. The questions include: How do the musicians react to the computer parts? 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 human could produce it, or rather as un-human thus potentially bending towards unheard artistic forms and aesthetics?

Risk management

The project organization will significantly minimize the risk of blocking problems by impulsing annual cycles of iteration between modelling, prototyping and experimentation/evaluation. This is achieved by distinguishing two distinct work-package clusters for fundamental approaches one one side and applied research and prototype production on the other, and by setting a transversal work-package for regulating experimentation with human experts. This will smooth out interactions between tasks, provide deliverables at a steady rate at the end of yearly cycles, and provide continuous control and collective decision handles to the project committee in order to process any emerging issue at a very early stage. Furthermore, each partner leads at least a major work-package and all the partners are involved in all the other work-packages, thus maximizing communication and efficiency between partners and maintaining a shared global vision throughout the project's duration.

The partner teams are internationally recognized as leaders in several fields addressed by this research, and participate in international networks of collaborations with prominent international institutions. They indeed provide an ideal combination of leading expertise and inter-disciplinary experience for a first-of-its-kind project. The PI's have successfully worked together in various configurations in the past, so the risk of misunderstanding or dysfunction in the consortium is very low and is further reduced by the interactive work organization.

Risks and challenges evaluation for each specific work-package are detailed in the Work Plan section below.

II. Organisation and implementation of the project

a. Consortium

IRCAM STMS Lab, coordinator partner, is a world leader institution in sound and music scientific research and artistic creation. The scientific coordinator, Gérard Assayag, has founded and currently heads the Music Representation team (RepMus) which is mainly involved in the project. G. Assayag has been Head of STMS Lab (UMR CNRS 9912) from 2011 to 2017 and as such he has been implicated in national and international research policies with a population of more than 100 persons staff in his jurisdiction. Assayag has created *OpenMusic*, an internationally renown composition software, and co-created OMax, the major reference in human-computer improvised interaction technology. Under Assayag's direction, RepMus has become a leading force in sound and music computing research, with the recent coordination of ANR projects DYCI2, MAKIMONO, INEDIT, EFFICACe, and its involvement in large international consortium such as SSHRC ACTOR. Joint researcher on this project Philippe Esling has created the RepMus ACIDS (Artificial Creative Intelligence and Data Science) research group bringing a strong expertise on machine learning methods such as deep learning or variational encoders and a new approach to creativity. RepMus will get help from other Ircam teams: S3AM (acoustics, mechatronics, signal processing, and physical modelling, head: T. Hélie) and ISMM (embodiment, gesture captation and modeling, head: F. Bevilacqua). It will get support as well as from the Ircam Music Production and Teaching Department for logistics in carrying the musical experiments.

EHESS CAMS Lab (Centre d'Analyse et de Mathématique Sociales, PI: Marc Chemillier) fosters a mathematical modeling approach in the study of human cultures as well as an anthropological approach to modeling (inter-)cultural practices and knowledge including musical ones. EHESS is the French leading institution in social sciences, and one of the most appraised institution of its kind in the world. PI Chemillier's work focuses on the modelling of oral knowledge, and more particularly on musical knowledge at the crossroads of anthropology, musicology, computer science and mathematics. Chemillier's models address the principles of coherence organizing this knowledge and its underlying logic, as well as the way in which this logic is conscious in the minds of the subjects, leading him to combine computational modelling and field research on the social and cognitive context of orality. Chemillier is an internationally leading figure in Ethnomathematics and the author of a critically acclaimed book on the subject exploring divination and music in several cultures. Chemillier is a long-time collaborator of Ircam RepMus team where he has been one of the co-creators of the OMax software family and where he has brought the methods of social science for the modelling of the knowledge at stake in musical improvisation (particularly in jazz), and more particularly in the changes brought about in artistic creation by the widespread use of new technologies. Mathematically, his musical modelling work is related to the field of word combinatorics and formal language theory.

HyVibe high-tech sound company (PI : Adrien Mamou-Mani) has developed the SmartInstrument, following the germinal researches led by Mamou-Mani at STMS Lab within ANR IMAREV project. HyVibe develops sound diffusion technologies based on vibration control, allowing optimal sound quality from any material surface. HyVibe has issued recently its first instrumental product, the HyVibe Guitar as a world premiere, putting HyVibe in a strong position of becoming a game changer in the music instruments industry. HyVibe has partnered with Algam (n°1 music distributor in France and n°4 worldwide) to power their Lâg Guitars by SmartInstrument technology. The award winning (NAMM 2019) Lâg HyVibe guitars are considered by experts as the archetype of the "smart revolution" in music (Music Inc.). They are commercialized in 2019 and will be distributed all over the world by the biggest distributors. The guitar market is a first step, HyVibe then wishing to conquer the sound broadcasting market, anticipating a fusion of these sound and music instruments markets. HyVibe aims to become the market leader in electroacoustic instrument components in the coming years (a position currently held by Fishman with $25 million in sales in 2017).

UCSD Lab CREL (Center for Research in Entertainment and Learning) (associated PI Shlomo Dubnov) will contribute closely to this project as non-funded external foreign partner, and we will benefit from the continuous help of **EPFL Meta Media Center** / Montreux Jazz Heritage Lab (Resp. Alain Dufaux). Pr. Dubnov and Dufaux are long time collaborators of Ircam RepMus Team and have brought unvaluable contribution to its previous projects in computational creativity. Pr. Dubnov is a world leader scientist in Musical Information Dynamics, an expertise essential to this project.

The consortium is highly complementary with Ircam handling creative artificial intelligence and musical informatics algorithmics, EHESS handling human and social science research and assessment and HyVibe mastering the technology and industrial production of active vibration control devices for mixed musical reality.

b. Work plan overview

<table>
<tr><td>Techno-logical prototypes providers</td><td>HA: Human Augmentation
(<u>HyVibe</u>, Ircam.)
Augment human abilities with mixed reality through Smart Instruments</td><td>CA : Cyber Augmentation
(<u>Ircam</u>, EHESS)
Augment digital agents abilities through computational creativity</td><td rowspan="3">ED: Experimentation, Validation, Dissemination
(Ircam, <u>EHESS</u>, HyVibe)
Use-cases, experimentations with musicians, scientific and artistic outreach, expert and basic users validation</td></tr>
<tr><td rowspan="2">Computa-tional and social science modelling tools providers</td><td colspan="2">DD : Deep Discovery (<u>Ircam</u>, EHESS)
Learning representation spaces for on-line discovery and generation of music structure</td></tr>
<tr><td colspan="2">AK : Anthropology of Improvised Practices (<u>EHESS</u>, Ircam, HyVibe)
Anthropological study of human and cyber-human improvisation</td></tr>
<tr><td></td><td colspan="2">R & D</td><td>Usage and outreach</td></tr>
</table>

Package coordinator is in **bold underlined.** Allocated resources (person.month) per partner between parentheses.

WP CO : Coordination

IRCAM (2), EHESS (1), HyVibe (1). M1 – M36.

Objectives This work-package will ensure the efficient management of the project and the coordination between partners

A project committee including all partners will meet on a regular basis 2 times a year minimum. The committee will overview the realization of the objectives and take decision to solve the technical and practical issues that could arise. Scientific seminars will be held three times a year in different configurations depending of the project stage in order to provide a frame for in-depth discussion and scientific watch. The coordination will be attentive to promote equal opportunities and to the best possible extent to gender balance. WP CO will deliver Consortium Agreement and Milestone Reports to the funding agency, as well as a series of tools for collaborative work between partners, communication and display toward the external world, such as project website, public repository (open-data and open-source code), social networking, internal shared calendar, mail lists, and sharing repositories.

Risks : The three partners have had successful collaborations in the past and the risks of organization or communication problems will thus be very limited.

Deliverables: *D.CO.1 Consortium agreement (M3), D.CO.2 Communications and collaborative tools (M6), D.CO.3 Report to ANR 1 (M18), D.CO.4 Report to ANR 2 (M36)*

WP AK: Anthropology of Improvised Practices

IRCAM (4), **EHESS (31),** HyVibe (41). M1 – M36.

Objectives : Anthropological, social and usage study of human and cyber-human improvisation dynamics.

Task AK.1 ***Introducing technological artifacts in live performances***

This task deals with the general problem of live perfomances integrating artifacts (computers, robots, mixed reality devices) competing or cooperating with humans according to different modes of human-machine interaction and collaborative robotics (Chemillier 2016). It is a major social and aesthetic challenge to question the presence of these machines on stage and to discover new humanistic ways of using them in order to enrich the experience of improvisation in diverse cultural backgrounds. An important part of this task will be to carry out a survey on the evolution of practices in the performing arts brought about by technological artifacts and to provide data and guidelines to WP CA and HA (in particular CA.1, HA.3)

Task AK.2 ***Rhythmic synchronization of humans and machines***

Adjusting the tempo of the machine with that of the other musicians is a difficult task and it requires experimentation sessions in order to collect empirical data as well as development of software components connected to innovative ergonomics. research conducted in musical cognition on group interaction in collective improvisation shows that there is no single tempo of reference, but as many tempos as musicians who are subject to some sort of negotiation and resynchronisation. In the long term, the challenge is to master the rhythm and acceptability of the machine's productions in relation to the requirements of phrase, flexibility and temporal precision that are characteristic of the subtle art of swing developed by jazzmen. This aspect of the project combines an empirical study on these synchronization phenomena with research on software solutions to integrate such strategies in relation with HA.2 and CA.2.

Task AK.3 ***Scenario based Improvisation induced from large corpus***

One aspect of improvisation softwares is to associate improvised musical phrases recombined from a learned corpus memory with an imposed harmonic chord progression (Nika 2017). The a priori harmonic knowledge on training data allows for efficient preprocessing and indexing methods to match patterns between the harmonic template and the improvisation memory. There are different strategies in the way jazzmen follow harmony (respecting harmonic contour or favoring melodic logic at the risk of generating dissonances with the underlying chords). Field surveys on the strategies employed by human experts of different cultures, including in cyber-human improvisation situations, will help collect data and guidelines for Creative agents design in DD.3 and CA.1.

Challenges, risks, solutions

The difficulty lies in the choices made in order to provide the other tasks with usable data and guidelines. Task ED will help in sequencing the cycles of iterations between field studies, data collection, model development and tool prototyping, so that the partners will be able to adjust their needs in terms of contents and formats.

***Deliverables**: D.AK.1 Report Cyber-human improvisation dynamics (M12, M24), D.AK.2 Report Rhythmic synchronization of humans and machines (M18, M30), D.AK.3 Report Scenario/Corpus based improvisation (M24, M36)*

WP DD : Deep Discovery

IRCAM (33), EHESS (4), HyVibe (4). M1 – M30.

Objectives : Learning representation spaces for on-line discovery and generation of music structure

Task DD.1 ***Multivariate embedding spaces for musical information and interaction***

The aim of this subtask is to conceive multimodal approaches able to learn joint embedding spaces linking symbolic, acoustic, performance and perceptual sources of musical information in interactive contexts by defining adequate information distances to minimize between semantically similar vectors in latent embedding spaces jointly learned with variational inference. We will generalize recent results obtained on generative variational timbre spaces (Esling et al. 2018) to multivariate streams. To do so, we will first study the disentanglement and topology of spaces learned in order to identify and discriminate information-carrying dimensions. Then, we will develop hierarchical temporal models that allow to ensure that the organization of these latent spaces follow a temporally-coherent organization. By using the lower-dimensional latent code as a distribution from which we can perform sampling, we will also experiment musically creative generative processes directly from these spaces in relation with CA.1 and CA.2.

Task DD.2 ***Predictive and interactive orchestration by machine learning***

The goal of this task is to integrate the learning processes of automatic harmonization and orchestration to perform co-improvisation with multiple instruments at once. This would widely increase the musical potential of co-improvisation algorithms to be able to generate full orchestral accompaniments in real time. The task will capitalize on previous work by team member of the project, Live Orchestral Piano, which is the first system able to perform the real-time orchestration of a piano input (Crestel and Esling, 2017) and by studying the possible extension of the model to co-improvisation situations and hierarchical generation (Carsault et al. 2018) relying on variational ladder networks. The learning on large sets of instruments in this hierarchical architecture poses high dimensionality problem that will require to develop specific approaches to optimizing the joint learning of latent space as reduced codes. This task will feed HA.1 and HA.2 with extended sound generation possibilities.

Task DD.3 ***Music generation and recognition preserving structure and style***

The aim of this subtask is to address the question of structure and style-constrained generation in creative machine learning algorithms. Indeed, most recent algorithms usually perform unconstrained and uncontrollable generation, while having large issues to produce coherent long-term structure and capture higher-level content such as form and style (related to CA.2 and AK.3). In this context, we intend to extend the algorithms developed in DD.1 to include style and structure conditioning on the latent spaces. To do so, we will rely on adversarial criterions and cycle consistency constraints in order to evaluate the style transfer of generated streams. Finally, in order to address the long-term style generation, we propose to extend the recent idea of generative flows to temporal scenarios. To do so, we will study the temporal behavior of flows in musical contexts.

Challenges, risks, solutions

The major risks of these task lie in the high dimensionality of the input data, the lack of significant style and structure-annotated musical data collections and mostly the lack of adequate evaluation measures. However, risks are limited by the success of the approaches proposed by members of the team that will serve as the basis for developing novel approaches. First, variational approaches will allow to overcome the dimensionality issues, while providing direct control through the latent spaces. Furthermore, several fallback solutions exist in the direct use of transfer learning to mitigate the lack of large datasets. Finally, regarding the evaluation metrics, the use of adversarial criterions will be investigated, but a clear fallback solution will be to evaluate the models with seminal measures such as physiological reactions or temporal interaction measures from WP AK.

***Deliverables**: D.DD.1 Report - Embedding spaces and multivariate time series (M12, M24), D.DD.2 Model - Predictive and interactive orchestration (M24), D.DD.3 Model of ML Music recognition and generation(M30)*

WP CA : Cyber Augmentation

IRCAM (31), EHESS (9), HyVibe (4). M1 – M30.

Objectives : Augment computational creativity of cyber-entities with enhanced perception, decision and communication skills so they can enter in expert and realistic improvised interplay with humans

Task CA.1 ***Enhancing creative agents awareness, autonomy and sociality skills***

This task aims to identify the most appropriate mecanisms for modeling creative agents (Assayag 2016) “mental” machinery and the way it is activated by “perception” of multi-variate streams of musical information coming from the external environment, in order to enhance their listening, understanding, decision-making, and generativity skills as well as their social interaction with other agents (in relation with AK.1). We will explore representation spaces (in relation with task DD.1) with semantic memory and reflexivity properties for simulating the qualities of awakening (curiosity triggered by a stimulus), attention (listening or not to other agents), motivation (whether or not agent wants to learn) and initiative (decide whether to play or not) in relation to computational models of self, belief and intentionality (self-model theory). This task is strongly related to HA.2 and HA.3 for Creative Instrument integration and with DD.3 for style simulation.

Task CA.2 ***Discovering multi-scale time structure from musical signal***

This task accounts for the higher-level cognitive phenomena involved in long-term memorization and creative production of phrase structures in musical improvisation by artificial agents. We will address the estimation of temporal shape emerging outside known idiomatic contexts (e.g. jazz, pop) or constituting variations of known idioms in uncertain performance context. To this effects, music information dynamics measures such as information rate (Dubnov, Assayag 2011), or correlation density will be tested to find structural boundaries. We will explore on-line learning methods such as long term / short term memory models (in relation with DD.2), in order to introduce temporal sensibility to the past in predicting the next structural units, in combination with statistical language models such as word sequence selection (Deguernel 2018), in order to efficiently induce phrase structure grammar. Results of this task will help allow CA.1 agents to enhance collective coordination by modeling belief on other agents’ long term strategy.

Task CA.3 ***Musical Information Dynamics as Model of Auditory Anticipation and Improvisation***

Modeling musical cognition involves multiple perception modalities, with expectancies playing one of the central roles in shaping the experience of musical structure. This is important in equipping the agents with listening skills in order to understand what the human musician is playing. We will explore possible relations between cognitive measures of musical structure and statistical signal properties that are revealed through information dynamics analysis. The questions addressed are: 1) description of music as an information source, 2) choice of musical features and dealing with their dependencies, 3) survey of different information measures and 4) characterization of listening experience w.r.t form expectancies. By enhancing the artificial perception of agents, this task is connected to CA.1-2, AK.2 and HA.2 .

Challenges, risks, solutions

These tasks connect advances in representation learning, artificial perception, creative agent architecture, so they should deliver highly efficient real-time tools, which can be tricky considering the complexity of underlying models. However preliminary results have shown that certain simplifications in the compressed representation of music signal preserve the essential information while easing things on the modelling load. Furthermore, less powerful existing tools available in preliminary results can be used until sufficient optimization is achieved.

***Deliverables**: D.CA.1 Prototype Enhanced Creative Agents I (M12), D.CA.2 Report Discovering multi-scale time structure (M24), D.CA.3 Prototype Enhanced Creative Agents II (M24), D.CA.4 Report Musical information dynamics (M30)*

WP HA : Human Augmentation

IRCAM (4), EHESS (4), **HyVibe** **(30**). M1 – M36.

Objectives : Augment human abilities for improvisation through multimodal access and mixed reality setup in Creative Instruments.

Task HA.1 ***Mixed Reality Using Active Vibration Technology on Musical Instruments***

The aim of this task is to design an embarked cyber-physical musical device for mixed musical reality. This object will follow two major objectives: 1) allowing humans to interact with artificial agents in a simple and creative way, and 2) producing a high-quality sound experience, where digital sounds merge perfectly with natural sounds. This will be achieved using the principles of smart instruments, based on active vibration technology and wireless connectivity. In addition to the existing setup used in HyVibe smart guitars, multiple sensors ("hexaphonic" for the guitar, using one sensor per string) will be added in order to finely measure and exploit human expression. Several actuators will be added in order to augment the hybridizing between acoustic and digital sounds, and to control the sound directivity for creative purposes. The addition of a wifi module will enable the transfer of long signals and data between the instrument and the remote server. A dedicated pedal will be also designed to pilot signals and data while playing.

Task HA.2 ***Embedding creative software agents in Creative Instruments***

This task will undertake the software and hardware integration of autonomous creative agents (CA.1-3) into the HyVibe hybrid architecture by first using generic electronic boards (type Raspberry Pi) to validate the coupling between low-level digital vibration processing, digital audio algorithms and creative AI algorithms, then by designing dedicated electronic board, performance optimization, test, and insertion in the physical instrument with control interface, delivering a first prototype of "Creative Instrument". Prototypes will be confronted to musicians in ED and AK.1-2.

Task HA.3 ***Embodied interaction for augmenting human skills on Creative Instruments***

The addition of creative algorithms in the smart instrument to make it a Creative Instrument will fundamentally alter the perception the musician has of his instrument and the way he acts upon it. This task will study the impact of this new situation on the physical, electronical, logical setup of the Creative Instrument and on the control strategies and interfaces it should implement in order to enhance the embodied interaction experience (in relation with AK.1). This task will also propose and experiment new applications such as Creative backing tracks, Creative improviser, Creative Looper, Creative Orchestrator etc. and combination thereof in relation with CA1-3, and AK2-3

Challenges, risks, solutions

These tasks aim at designing the first Creative Instrument. Bridging active vibration control to creative AI is very challenging, in term of hardware and software design. Creative AI will fundamentally alter the natural vibration of the instrument, generating increased haptic feedback, acoustic feedback, and acoustic interferences. These effects are a risk as they will affect the functioning of the instrument and the quality of the musician's experience. However, the user experience already accumulated around the HyVibe guitar and further experimentation in WP AK and ED will help to identify possible conflicts in the musician's undertaking and the instrument's affordance and tune the system accordingly.

***Deliverables**: D.HA.1 Prototype - Mixed reality with active vibration (M18), D.HA.2 Report - Embodied interaction on creative instruments(M18), D.HA.3 Prototype - Creative Instrument I (M24), D.HA.4 Prototype - Creative Instrument II (M36)*

WP ED: Experimentation, Validation, Dissemination

IRCAM (1), **EHESS (2)**, HyVibe (2). M6 – M36.

Objectives : Use-cases, experimentations with musicians, scientific and artistic outreach, expert and basic users validation

This researches will be conducted in constant collaboration with expert musicians including world class performers, thanks to IRCAM Music Creation and Production support, and to the Montreux Jazz Festival and EPFL Metamedia department who kindly provide us with the digitized festival archive (the first audiovisual collection to be inscribed in the UNESCO immaterial Memory of the World) and help us involve great live musicians. The models delivered by research packages will be tested, refined and validated during experimentation sessions combining social science experiments (conducted by AK) using participant observation in studio and public concerts, video capture of these events, critical re-listening sessions, musician interviews and debriefing. This task will also include experiments with well-trained music students during workshops that we will organize in order to collect data from both amateur and professional musicians.

In addition to publications in the major conference in the domain (SMC, ICMC, ISMIR, ACM Multimedia, ICCC, NIME, MOCO, CHI, ICSC etc.) and scientific seminars organized by the project committee, two editions of the international workshop – festival ImproTech will be organized during the course of the project. Improtech has been created by two of the PI's (G. Assayag and M. Chemillier) and is recognized as the leading international meeting for scientific and artistic research and creation, at the interface of improvisation and computer science and technologies. ImproTech will be an invaluable platform for displaying the Creative Instrument research results and benefit from the feedback of the whole scientific and artistic community.

***Deliverables**: D.ED.1 Report on experimentation, user feed-back and validation I (M18), D.ED.2 International workshop and festival I (M18), D.ED.3 Report on experimentation, user feed-back and validation II (M36), D.ED.4 International workshop and festival II (M36)*

Work plan summary : time-line and deliverables

Work Plan

	persons/m :	IRCAM	EHESS	HyVibe	Year 1 Sem 1	Year 1 Sem 2	Year 2 Sem 3	Year 2 Sem 4	Year 3 Sem 5	Year 3 Sem 6
WP CO	**Coordination**	2	1	1	X		X			X
CO	Project Management									
WP AK	**Anthropology of Improvised Practices**	4	31	4		X	X	X	X	X
AK.1	Introducing technological artifacts in live performances									
AK.2	Rhythmic synchronization of humans and machines									
AK.3	Scenario based improvisation induced from large corpus									
WP DD	**Deep Discovery**	33	4	4		X		X	X	
DD.1	Multivariate embedding spaces for musical information and interaction									
DD.2	Predictive and interactive orchestration by machine learning									
DD.3	Music generation and recognition preserving structure and style									
WP CA	**Cyber Augmentation**	31	9	4		X		X	X	
CA.1	Enhancing creative agents awareness, autonomy and sociality skills									
CA.2	Discovering multi-scale time structure from musical signal									
CA.3	Musical information dynamics for auditory anticipation and improvisation									
WP HA	**Human Augmentation**	4	4	30			X	X		X
HA.1	Mixed reality using active vibration technology on music instruments									
HA.2	Embedding creative software agents in creative Instruments									
HA.3	Embodied interaction for augmenting human skills on creative Instruments									
WP ED	**Experimentation, Validation, Dissemination**	1	2	2			X			X
ED.1	Experimentation, validation, user feed-back									
ED.2	Dissemination workshops									

Deliverables

M6

D.CO.1 Consortium agreement
D.CO.2 Communications and collaborative tools

M12

D.AK.1 Report Cyber-human improvisation dynamics
D.DD.1 Report Embedding spaces and multivariate time series
D.CA.1 Prototype Enhanced Creative Agents I

M18

D.CO.3 Report to ANR 1
D.AK.2 Report Rhythmic synchronization humans/machines
D.HA.1 Prototype Mixed reality with active vibration
D.HA.2 Report Embodied interaction on creative instruments
D.ED.1 Report on experimentation, user feed-back and validation I
D.ED.2 International workshop and festival I

M36

D.CO.4 Report to ANR 2
D.AK.3 Report Scenario/Corpus based improvisation (revised)
D.HA.4 Prototype Creative Instrument II
D.ED.3 Report on experimentation, user feed-back and validation II
D.ED.4 International workshop and festival II

M30

D.AK.2 Report Rhythmic synchronization humans/machines (revised)
D.DD.3 Model of ML Music recognition and generation
D.CA.4 Report Musical information dynamics

M24

D.AK.1 Report Cyber-human improvisation dynamics (revised)
D.AK.3 Report Scenario/Corpus based improvisation
D.DD.1 Report Embedding spaces and multivariate time series (final)
D.DD.2 Model Predictive and interactive orchestration
D.CA.2 Report Discovering multi-scale time structure
D.CA.3 Prototype Enhanced Creative Agents II
D.HA.3 Prototype Creative Instrument I

c. Project budget

Requested means by category / partner

		Partner *IRCAM*	Partner *EHESS*	Partner *HyVibe*
Staff expenses permanent		164 000 €	112 000 €	105 120 €
Staff expenses non permanent (recruited for the project)		166 320 €	112 000 €	114 000 €
Instruments and material costs (including consumables)			5 000 €	10 000 €
Building and ground costs				
Outsourcing / subcontracting		15 000 €	10 000 €	30 000 €
General and administrative costs & other operating expenses	Travel Costs	25 000 €	12 000 €	
	Admin. management & structure costs **	227 418 €	11 120 €	75 110 €
Sub-total		**597 738 €**	**150 120 €**	**334 230 €**
Funding cost model		Full cost, financed at 50%	Marginal cost, financed at 100% not including permanent staff	Full cost, financed at 45%
Requested funding		**298 869 €**	**150 120 €**	**150 403 €**
Total Requested funding		**599 392 €**		

** For marginal cost beneficiaries, max 8% of the eligible expenses. For full cost beneficiaries, max 68% of staff expenses and 7% of other expenses.

Justification of requested aid by partner

IRCAM

Staff expenses

IRCAM provides 35 persons.month of senior level permanent research staff (M1-M36, 164K€) working mainly on WP CO, CA and DD and contributing significantly to WP AK, HA and ED (see details in the Summary table of personnel at the beginning of the doc). Please note only 25 p.m. are indicated on the ANR submission site as P. Esling is a professor at Sorbonne University, thus not counted in Ircam full cost salary calculation.

Non-permanent staff recruited for the project:

Post-doc1 (24 monthes, M6-M30, 111K€) supervised by G. Assayag will be focused on Creative Agents modelling and architecture in WP CA and will help coordinate embedding of creative agents within mixed reality creative instruments in WP HA.

Post-doc2 (12 monthes, M12-M24, 55K€) supervised by P. Esling will be focused on Creative Artificial Intelligence models including predictive orchestration and deep representation learning in WP DD, and will help coordinate the integration of models in prototypes with WP CA and HA.

Other costs

IRCAM will handle the organisation of the international workshop festival ImproTech (M18 and M36) as it has the know-how for managing cultural events, involving costs for paying abroad event management subcontracting (15K€). Mission expenses (25K€) include both the usual operations (average 1 international and two national conferences per year for 2 researchers and 1 postdoc) and support to Improtech scholar invitations.

Ircam provides its large integrated production and experimentation facilities (professional recording studios, audio and instruments equipment, experimental rooms and equipment, plus the technical staff including sound engineers and computer music designers as needed) to all project members, justifying its higher administrative overhead.

EHESS CAMS

Staff expenses

EHESS provides 24 monthes of permanent senior researcher (M1-M36, 112K) mainly on WP AK and ED and contributing significantly to WP CA and AH, with 3 monthes of a PhD candidate (M1-M12, independent funding not shown in budget table).

A non-permanent post-doc is recruited for the project (24 monthes, M6-M30, 112K€) who will focus on scenario-based improvisation and rhythmic studies in WP AK and contribute to WP CA and AH, and will also help in setting up experiments with musicians and collecting data for WP AK and DD.

Other costs

Computer and audio Equipment : 5K€ ; Mission expenses : 12K€ (average 1 international and two national conferences per year for 1 researchers and 1 postdoc) ; subcontracting and fees : 10K€ (experiments with musicians, logistics)

HyVibe

Staff expenses

HyVibe provides 21 months (M1-M36, 105K€) of permanent staff (2 PhD trained CEO/CTO executives and a Marketing expert) and will recruit an engineer (24 months, M12-M36, 114K€) who will develop the Mixed reality setup and the Creative Instruments prototypes in WP HA in close coordination with WP CA.

Other costs

Equipment : 10K€ (workstation, development kit, measuring test bench), outsourcing / subcontracting : 30K€ (board design, IP, lutherie integration)

III. Impact and benefits of the project

a. ANR 2019 themes and priorities matching

Generalized Human-machine interaction involving improvisation with autonomous agents and creative contents generation, embodied instrumental interfaces with mixed reality, and innovative machine learning tools in creative artificial intelligence, make the MERCI project totally fitted for the **Interaction, Robotique** scientific axis of the call, in the « Sciences du numérique » domain.

Furthermore, MERCI is at the confluence of the two strategic priorities that the French government wishes to support in 2019 through national research calls : Artificial intelligence (Govt Plan “IA”) is highly developed in MERCI in an interdisciplinary setup bringing data science together with anthropology and computer music ; Human and social sciences (govt Plan “SHS”) is another key component with a work package entirely dedicated to anthropological assessment of improvised practices and knowledge, with important artistic creation, cultural heritage, human learning and cognition issues.

b. Scientific and societal impact

This project constitutes a unique opportunity of opening new research avenues and produce groundbreaking technological prototypes, as it is the first time that the notion of improvisation is brought as a general scheme for collective human and cyber-human communication and interaction, with a highly inter-disciplinary effort to augment human abilities through musical mixed reality and computational co-creativity. More specifically in terms of machine learning and cognition, it is the first structured initiative to foster modelling of human creativity as a rational basis to understand complex and intricate phenomena with deep multimodal embedding spaces linking learning mechanisms, interaction and creativity so that each can feed the other. Creative applications developed in this project also present a high potential for future economic outcomes: it is worth noting that In 2014, guitarists spent more than $4.25 billion on guitars, amplifiers and effects pedals, with 3.75 million acoustic guitars sold. 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 time and pleasure of use as well as the creativity of musicians thus helping seduce and retain them in a constantly renewed esthetic experience.

Mixed reality acoustic instruments embedding creative musical intelligence such as the Creative Instrument are clearly the new frontier in music industry and the prototypes produced by MERCI will create a powerful momentum in the technological as well as in the societal domain. As for the partners, HyVibe’s innovative capacity and technological advance will undoubtedly be enforced by our shared research, while Ircam and EHESS will renew their research methods, enlarge their scope and notably deepen their social reach.

In addition to open-source code, empirical human data from live interaction experimentation in WP AK, and annotated orchestration data sets from WP DD will be released as open-access bases to provide reference material for the scientific community (e.g. ImproTech) and other communities (e.g. augmented instrument design).

c. Technology and innovation transfer to the social and economic world

The strategy of this project is to transfer technology and scientific innovation in Creative Artificial Intelligence from two major labs, Ircam-STMS and EHESS -CAMS to an industrial partner, HyVibe, who has already set the basis for an important social and economic transformation in the realm of instrumental music practice, by delivering the first SmartInstrument, the HyVibe Guitar, shipping worldwide since a few months. This transfer, concentrated in the cooperation of the CA and HA work Packages in MERCI, will transform the SmartInstrument in Creative Instrument, i.e. an instrument with embarked music intelligence in the form of Creative software agents. The HyVibe guitar will serve as the first market test for the new technology produced by the project and once this transfer has been made and validated technically, the entire musical instrument industry and musical research networks will be able to benefit from it. As Ircam and EHESS have a long story of collaboration in this field, and HyVibe itself is partly a descendant of Ircam fundamental researches, the technology transfer between partners is in the best possible conditions of smoothness and efficiency. The MERCI project will deliver prototypes (software and integrated instrument) that will be directly tested and ameliorated by HyVibe among its international base of users and customers. In the future (after MERCI results have been fully understood and integrated), it is our hope that new partners will then enter the game and be able to produce the human, technical and financial investments necessary to follow up and create new devices, test and validation chains, bring into play the essential technology transfers from public research to business, and contribute to the global organisation and competitiveness of the Creative Instruments economical sector.

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