legos project

Sensori-motor learning in gesture-sound interactive systems

LEGOS DAYS 2015

INTERNATIONAL WORKSHOP

ON MOVEMENT SONIFICATION AND LEARNING

March 2–3, 2015

IRCAM, Paris, France

http://legos.ircam.fr

This workshop marks the end of the *Legos* project, which focused on sensori-motor learning in gesture-sound interactive systems. The goal of this event is to report on the major results, illustrated with demonstrations, and discuss current trends and emerging applications (such as rehabilitation, music, sport, well-being) with guest researchers.

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Local Organization Committee

STMS UMR 9912 IRCAM - CNRS - Université Pierre et Marie Curie
Laboratoire de Psychologie de la Perception UMR CNRS 8242 – Université Paris Descartes

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Monday, March 2, 2015

All talks are in the Stravinsky room (level 0) and demos in the Shannon room (level -2)

9:00 – 9:30	Registration (IRCAM lobby)
9:30 – 10:00	**Introduction: the Legos Project** Frédéric Bevilacqua, IRCAM – Sylvain Hanneton, UMR CNRS 8242 – Université Paris Descartes
10:00 – 10:45	**Moving Better: How Can Sound Help?** Cathy Craig (invited), Queen's University Belfast, School of Psychology
10:45 – 11:15	Pause / Coffee (gallery level -2)
11:15 – 12:00	**Continuous Auditory Feedback for Sensorimotor Learning** Eric Boyer, Sylvain Hanneton, Patrick Susini, Frédéric Bevilacqua IRCAM & UMR CNRS 8242 - Université Paris Descartes
	Lunch break
14:00 – 14:45	**Movement Sonification, Multisensory Integration and Motor Learning** Alfred Effenberg (invited), Leibniz Universität Hannover
14:45 – 15:30	**Movement Sonification Tools and Methods** Jules Françoise, Norbert Schnell, Frédéric Bevilacqua, IRCAM
15:30 – 16:00	Discussion
16:00 – 16:30	Pause / Coffee (gallery level -2)
16:30 – 18:00	**Demos** (Shannon room, level -2)

Tuesday, March 3, 2015

All talks are in the Stravinsky room (level 0) and demos in the Shannon room (level -2)

9:30 – 10:15	**Rhythmic Walking Interactions with Ecological Audio-Haptic Feedback** Stefania Serafin, (invited) Aalborg University Copenhagen, Medialogy
10:15 – 11:00	**Rhythmic Cueing for Improving Gait in Parkinson's Disease** Simone Dalla Bella, (invited) Université Montpellier II, Movement To Health
11:00 – 11:30	Pause / Coffee (gallery level -2)
11:30 – 12:15	**Sonification of the Arm Coordination** Agnès Roby-Brami, Eric Boyer, Nathanël Jarrassé, Frédéric Bevilacqua, ISIR-UPMC / IRCAM
12:15 – 12:45	Discussion
	Lunch break
14:30 – 15:15	**Translating Pen Movements into Sounds and Music to Facilitate Handwriting Rehabilitation** Jean-Luc Velay (invited), Jérémy Danna, Université Aix-Marseille
15:15 – 16:00	**Manipulating Sonified Objects** Olivier Houix, Nicolas Misdariis, Patrick Susini, Frédéric Bevilacqua, IRCAM
16:00 – 16:30	Pause / Coffee (gallery level -2)
16:30 – 17:30	Final Discussion

Monday

◆ 9:30 – 10:00

Introduction to the Legos project

The LEGOS project is a collaborative research project that focuses on sensorimotor learning in gesture-sound systems (the consortium includes *IRCAM and UMR CNRS 8242 – Université Paris Descartes).* We develop and evaluate movement based interactive systems, taking into account motor adaptation and learning at its core. We also aim at establishing novel methods towards movement sonification for medical applications such as rehabilitation. We consider three different perspectives: 1) Gesture learning where the task is to perform a gesture guided by an audio feedback (e.g. rehabilitation) 2) Movement-based sound control where the task is to produce a given sound through the manipulation of a gestural interface (e.g. in digital musical instruments) 3) Interactive sound design where the task is to manipulate an object or a tangible interface that is sonified.

Frédéric Bevilacqua, Sylvain Hanneton

IRCAM & UMR CNRS 8242 – Université Paris Descartes

> Frédéric Bevilacqua is the head of the Sound Music Movement Interaction team at IRCAM in Paris (part of the joint research lab Science & Technology for Music and Sound – IRCAM – CNRS – Université Pierre et Marie Curie). His research concerns the modelling and the design of interaction between movement and sound, and the development of gesture-based interactive systems. He holds a master degree in physics and a PhD in Biomedical Optics from EPFL in Lausanne. He also studied music at the Berklee College of Music in Boston and has participated in different music and media arts projects. From 1999 to 2003 he was a researcher at the Beckman Laser Institute at the University of California Irvine. In 2003 he joined IRCAM as a researcher on gesture analysis for music and performing arts.

> Sylvain Hanneton, alumni of the Ecole Normale Supérieure (Paris, s89) has a PhD in Biomathematics from the Pierre et Marie Curie University. He was directed by Dr. Jacques Droulez in the Laboratory of Perception and Action Physiology (LPPA, Dir. Alain Berthoz). After his PhD he works on theoretical approaches of movement control by the brain and especially perceptual learning at the UTC (Université de Technologie de Compiègne) COSTECH Lab (dir. Charles Lenay). Lecturer (Maître de Conférences, Assistant Professor) at the Paris Descartes University since 1999, he teaches in the Sport Sciences Department and is a member of the "AVoC" team of the Laboratory of Psychology of Perception (CNRS UMR 8158). SH is also the executive manager of the VHMA master (Aging, Handicap, Movement and Adaptation) and co-manager of the sensorimotor motion capture plateform of the Paris Descartes University.

◆ 10:00 – 10:45

Moving Better: How Can Sound Help?

Our survival in the ever-changing world we live in requires that we pick up and use sensory information from our environment so that we can successfully interact with other objects and/or people. More specifically, changing patterns of sensory stimuli provide the brain with important information that allows us to organise and control our actions ahead of time. In this presentation I will explore how the brain can use this sensory information to guide movement. More specifically, I will discuss how we can harness the power of dynamic sensory stimuli, in particular sound, to create auditory guides that help improve the control of our actions. In the first example will look at how sound can help improve the consistency of action when learning to perform a new self-paced skill, that draws on the main principles involved when putting a ball in golf. The second example will explore how sound can be effectively used to help improve movement performance in people with Parkinson's disease. Limitations associated with sound synthesis along with the future direction this emerging area of research could take will be discussed.

Monday

Professor Cathy Craig

Queen's University Belfast, School of Psychology

Having graduated from Edinburgh University (MA and PhD in Psychology), Professor Cathy Craig worked for 8 years as a lecturer at the Sports Science Faculty, at the University of Aix-Marseille France. In 2005 she joined the psychology department at Queen's University Belfast as a senior lecturer and was promoted to professor in 2010. She is now the Head of School of Psychology and the Director of the Movement Innovation Lab. Being the recipient of a prestigious European Research Council grant in 2008, she has been able to build a state of the art research facility to study how our brain controls everyday actions. Her particular interest is in how perceptual information picked up through our senses can be exploited to help improve movement performance. She uses innovative methods such as immersive interactive virtual reality and gaming technology to create computer generated environments that help train and improve movement. She has used this technology to understand decision making in sport (e.g. rugby, soccer, cricket), create bespoke balance training games for older adults and improve gait in people with Parkinson's using sound.

◆ 11:25 – 12:00

Continuous Auditory Feedback for Sensorimotor Learning

We have acquired, through our sensorimotor system, a strong relationship with the auditory space that surrounds us. We have implicitly learned to integrate the sound of our actions and use them everyday. The development of motion sensing and audio technologies makes it possible to design specifically auditory feedback through the *interactive sonification* of movement features. We propose several experimental frameworks to assess the contribution of auditory feedback to sensorimotor control and learning in interactive systems. First, we studied the processing of spatialized auditory feedback for online motor control. Second, in a visuo-manual tracking task, we found that both error and task sonification can improve the performance while implying learning mechanisms. We also show that the sonification of user's movement tends to increase the motion energy. Finally, we present the concept of sound-oriented task, where the target is expressed as acoustic features to produce through a movement, demonstrating that motor adaptation can be driven by interactive audio cues only. Overall, we argue that continuous movement sonification should be further investigated in auditory-motor coupling research, and we highlight important applications through original setups we developed, like perceptual and physical training, and playful scenarios for rehabilitation.

Eric Boyer, Sylvain Hanneton, Patrick Susini, Frédéric Bevilacqua

IRCAM & UMR CNRS 8242 - Université Paris Descartes

Éric Boyer obtained a Master's degree in acoustics engineering in 2009 from École Nationale Supérieure d'Ingénieurs du Mans. After several research projects on musical instruments (including vibro-acoustic modeling of the Cristal Baschet), he worked on a process for instrument radiation measurement and reproduction using multi-loudspeaker arrays at IRCAM. From 2010 to 2011, he worked as a project manager for building, environmental and industrial acoustics in a consulting office in southern France. In 2012, he joined the Sound Music & Motion Interaction team of IRCAM and the Psychology of Perception Lab of Paris Descartes University as a PhD candidate in the framework of the Legos project. His PhD focuses on the role of auditory feedback in gesture-sound interactive systems, particularly on the use of continuous movement sonification for sensorimotor-learning.

Monday

◆ 14:00 – 14:45

Movement Sonification, Multisensory Integration and Motor Learning

If additional acoustic movement information is configured adequately, motor perception can be enhanced and thus processes of motor control and motor learning in different fields of application (sports, motor rehabilitation, everyday movements) can be supported effectively. Movement sonification is an appropriate method for generating such kind of supportive information. Sonification based on dynamic as well as kinematic movement parameters is introduced and the obtained effects in sports and motor rehabilitation are described. Neurophysiological evidence on the effectiveness of movement sonification is presented additionally.

Professor Alfred Effenberg

Leibniz Universität Hannover

Professor Dr. Alfred Effenberg is a full professor of Sports Science at the Leibniz University Hanover, Institute of Sports Science, and head of the working area "Movement & Exercise Science". His research interests concern motor perception, motor control, motor learning, perception-action coupling, multisensory integration and movement sonification. He holds a PhD in Sports Science from the University of Hamburg and a Habilitation in Sports Science from the University of Bonn. He was recently the organizer of the International Conference "Multisensory Motor Behavior: Impact of Sound", that was held in 2013 in Hanover, Germany. At the European level, he is the coordinator of the EU-ERDF Joint Project "Movement-Sonification" and principal investigator in the EU H2020 project "socSMCs – Socializing Sensori-Motor Contingencies".

◆ 14:45 – 15:30

Movement Sonification Tools and Methods

We present several tools we developed for designing interactive sonification strategies. In particular, we developed an ecological approach of continuous movement sonification we call "mapping by demonstration". The relationship between motion and sound is defined by providing movement examples performed while listening to sound examples. The system automatically learns the motion-sound mapping by jointly modeling movement and sound data. The system integrates specific probabilistic models with hybrid sound synthesis models. We will describe and demonstrate two specific implementations of the mapping by demonstration method. The first one makes use of the Leap motion to sonify movement with sound textures. The second system makes use of inertial measurement units and vocalizations as sound material.

Jules Françoise, Norbert Schnell, Frédéric Bevilacqua

IRCAM

Jules Françoise is a PhD candidate in the "Interactions Sound Music Movement" Team at IRCAM, under the supervision of Frédéric Bevilacqua. After a Master's degree in acoustics, he shifted towards Computer Science during his Master degree ATIAM at IRCAM to study gesture interaction with sound in interactive musical systems. Currently, he focuses on modeling gesture, sound, and their mapping for expressive control of sound synthesis, with specific interests in the articulation between machine learning and human–computer interaction.

Tuesday

◆ 9:30 – 10:15

Rhytmic Walking Interactions with Ecological Audio-Haptic Feedback

In this talk we present a series of experiments whose goal is to investigate the role of auditory and haptic feedback in facilitating rhythmic walking in place. We describe how different modalities (auditory and haptic) as well as the kind of feedback provided (ecological or none) affect walking.

Professor Stefania Serafin,

Aalborg University Copenhagen, Medialogy

Stefania Serafin is Professor with special responsibilities in sound in multimodal environments at Aalborg University in Copenhagen. She has been Associate Professor (2006-2012), and Assistant Professor (2003-2006) at Aalborg University Copenhagen. She received a Ph.D. in Computer Based Music Theory and Acoustics from Stanford University in 2004, and a Master in Acoustics, Computer Science and Signal Processing Applied to Music from IRCAM (Paris) in 1997. She has been visiting professor at the University of Virginia (2003), and visiting scholar at Stanford University (1999), Cambridge University (2002) and KTH Stockholm (2003). She is principal investigator for the EU funded project Natural Interactive Walking, and Danish delegate for the EU COST Action on Sonic Interaction Design. Her main research interests are sound models for interactive systems and multimodal interfaces, and sonic interaction design.

◆ 10:15 – 11:00

Rhythmic Cueing for Improving Gait in Parkinson's Disease

Rhythmical auditory stimulation can be used successfully in the rehabilitation of motor function in patients with motor disorders. A prototypical example is provided by dysfunctional gait in patients with idiopathic Parkinson's disease (IPD). Coupling steps to external rhythmical cues (the beat of music or the sounds of a metronome) leads to long-term motor improvements such as increased walking speed and greater step length. These effects are likely to be underpinned by compensatory brain mechanisms (e.g., cerebellar-thalamo-cortical regions), which are also involved in perceptual and motor timing. Thus, parallel improvement in timing tasks is expected in IPD beyond purely motor benefits. In keeping with this idea, data will be presented that show beneficial effects of auditory cueing in IPD in both perceptual and sensorimotor timing tasks. Particular attention will be paid to individual differences in timing abilities in IPD as a way to drive cueing-based therapy, and to technological solutions which allow 1) to assess those individual differences, and 2) to implement individualized cueing-based programs.

Professor Simone Dalla Bella

Université Montpellier II, Movement To Health

Simone Dalla Bella studied cognitive psychology at the University of Padua (Italy), completed a PhD in cognitive neuropsychology at the University of Montreal (Canada), and received a Habilitation degree from the University of Warsaw (Poland). He also obtained a Master degree in piano performance from the Conservatory of music of Mantua (Italy). He is Professor in movement sciences at the University of Montpellier 1 (France), junior member of the Institut Universitaire de France, and associate member of the BRAMS laboratory (Montreal). He currently directs the Rhythm & Synchronization Team in the Movement to Health Laboratory (EuroMov, Montpellier, France). His research interests concern the neurosciences of music and rhythm with a particular focus on music disorders in the general population (tone deafness and beat deafness), and rhythm/pitch perception and production mechanisms in the general population, professional musicians, and patients with brain damage (e.g. with Parkinson's disease).

Tuesday

◆ 11:30 – 12:15

Sonification of the Arm Coordination

The sonification of human movement is a growing research topic, with early results showing promise in a wide range of applications, such as performing arts, rehabilitation and sports training. Our long-term goal is to investigate the particular case of sonification of arm movements for the rehabilitation of stroke patients. This involves providing patients with auditory feedback relative to the coordination between shoulder and elbow motion, and relative to movement smoothness. For this purpose, we are exploring different types of sonification and musical metaphors, and various sound synthesis techniques. This includes very simple methods such as filtering noise as well as more complex methods such physical modelling sound synthesis and concatenative and granular sound synthesis. In order to evaluate first these different techniques on normal patients, we developed a methodology using a motorized splint, which allows us to alter the arm coordination. We report here our experimental methods and preliminary results.

Agnès Roby-Brami, Eric Boyer, Nathanël Jarrassé, Frédéric Bevilacqua

ISIR-UPMC & IRCAM

> Agnès Roby-Brami received the MD degree from the University Paris Descartes, in 1982, and the MSc and the PhD degrees and University Habilitation in Neurosciences from Pierre et Marie Curie University, Paris, France, in 1982, 1991, and 2001, respectively. She is a physician who performed her residency in Paris Hospitals during 1977–1982. She was appointed as a Research Associate at INSERM in 1983 and promoted to Research Director in 2005. Her first research interest was in the field of clinical neurophysiology after which she focused on upper limb motor control, disability, and recovery in cerebral and spinal injured patients. She is the author or coauthor of 83 peer-reviewed academic publications, and 44 contributions to edited books. She is also actively involved in several Academic Networks concerning research on disability.

◆ 14:30 – 15:15

Translating Pen Movements into Sounds and Music to Facilitate Handwriting Rehabilitation

The mastering of handwriting is so essential in our society that it is important to try to find new methods for facilitating its learning and rehabilitation. Up to now, the quality of handwriting was evaluated from the visual inspection of its legibility and not from the movement that generates the trace, although the ability to control the graphic movements clearly impacts on the quality of the writing. New technologies improve existing techniques or enable new methods to supply the therapist with new diagnostic tools and the writer with real-time computer-assisted feedback. In particular, sounds can be used to inform about the correctness of an on-going movement, without directly interfering with the visual and proprioceptive feedback. Furthermore, the dynamic features of sounds make them particularly appropriate means of accessing the spatiotemporal characteristics of movements. Finally, because of their playful characteristics, sounds are potentially effective for motivating children in particular need of such assistance. We will present experimental data suggesting that transforming kinematic variables into sounds might be a relevant tool allowing a therapist to complete the visual assessment of the written trace by an auditory control of the handwriting movement quality. Furthermore, both adults with a proprioceptive loss and dysgraphic children are able to write faster and with more fluent movements with the aid of auditory feedback. We propose that sounds and music may be used as a palliative way to assist handwriting movement learning and rehabilitation.

Jean-Luc Velay and Jérémy Danna
Université Aix-Marseille

Jean-Luc Velay received a PhD degree in Neurosciences from Aix-Marseille University, France in 1984. After a post-doctoral training under the supervision of P. Viviani in Milan (Italy), where he studied visual perception and oculomotor control, he was recruited as permanent senior researcher by the French Centre for Scientific Research (CNRS) in 1986. He is currently in the Cognitive Neurosciences Laboratory in Marseille. During several years, Jean-Luc Velay has been studying the role of arm and eye proprioception both in motor control and space perception in Human. He then became interested in the control of a particular movement serving language, namely handwriting. Using a MRI, he studied the cognitive and brain processes involved in handwriting production and perception, and the interconnections between reading and handwriting. In particular, he studied the cognitive and cerebral consequences of the increasing moving from handwriting to typing. In addition, he has been working on the handwriting troubles and their links with other learning troubles, as dyslexia and developmental coordination disorders (DCD). An important topic in his team concerns the relationships between music production and perception and oral and written language: using music as a means of reducing language troubles in dyslexic children, for instance.

◆ 15:15 – 16:00

Manipulating Sonified Objects

In standard human-computer interaction paradigms, there is generally a separation between the gestural interaction and potential sound feedback: the sound is not designed to be the result of the physical interaction with the interface. In contrast, we are interested to explore sonic interaction paradigms where the sound feedback informs the listeners of their actual gestures and actions. We will present examples of interactive objects integrating dynamic sound feedback. This allows for improving the tangible object manipulation and learning. Sound feedback can also alters emotional aspects. In particular, we present the development of sonic interactive objects called "Stonic". They are designed to provide users with different affordances, i.e. action possibilities, which are linked to different sound feedbacks. These objects are used for experimental studies to better understand and model augmented auditory feedback in object manipulations.

Olivier Houix, Nicolas Misdariis, Patrick Susini, Frédéric Bevilacqua
IRCAM

Olivier Houix obtained a PhD degree in acoustics in 2003 from the Université du Maine, Le Mans, France. His research interests concern the perception of environmental sounds and the gesture-sound relationship applied to sound design. He teaches sound practice in the Master of Sound Design program at the Fine Arts school in Le Mans. A member of the Sound Design and Perception Team at IRCAM, he has participated in national and European projects such as CLOSED. He also took part in the Legos project that studied sound-gesture relationships and the European project Skat-VG (Sketching Auditorily with Vocalizations and Gestures).

Nicolas Misdariis is a research fellow and the co-head of IRCAM / Sound Perception and Design team. He studied at CESTI-SupMeca, an engineering school specialized in mechanics. He obtained a Master's degree in acoustics at LAUM (Le Mans) and a PhD at CNAM (Paris) on synthesis/reproduction/perception of musical and environmental sounds. Since 1995, he has worked at IRCAM as a researcher where he has taken part in several projects concerning research dealing with sound science and technology. In 1999, he contributed to the constitution of the IRCAM / Sound Design team where he has developed works related to sound synthesis, diffusion technologies, environmental sound and soundscape perception, auditory display or interactive sonification. Since 2010, he is also a lecturer within the Master of Sound Design in the Fine Arts school at Le Mans.

Patrick Susini received a PhD degree and a Habilition in Psychoacoustics. He is the head of the Sound Perception and Design group at IRCAM. His activities include research on loudness and everyday sound perception, and applications in sound design. He has coordinated several industrial, national (ANR) and European (FP7) projects. He teaches psychoacoustics, psychophysics, and sound design.

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