Activity Report 2018

Project-Team EX-SITU

Extreme Situated Interaction

IN COLLABORATION WITH: Laboratoire de recherche en informatique (LRI)

RESEARCH CENTER
Saclay - Ile-de-France

THEME
Interaction and visualization
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Project-Team EX-SITU

Creation of the Team: 2015 January 01, updated into Project-Team: 2017 July 01

Keywords:

**Computer Science and Digital Science:**
- A5.1. - Human-Computer Interaction
- A5.1.1. - Engineering of interactive systems
- A5.1.2. - Evaluation of interactive systems
- A5.1.5. - Body-based interfaces
- A5.1.6. - Tangible interfaces
- A5.1.7. - Multimodal interfaces

**Other Research Topics and Application Domains:**
- B2.8. - Sports, performance, motor skills
- B5.7. - 3D printing
- B6.3.1. - Web
- B6.3.4. - Social Networks
- B9.2. - Art
- B9.2.1. - Music, sound
- B9.2.4. - Theater
- B9.5. - Sciences

1. Team, Visitors, External Collaborators

**Research Scientists**
- Wendy Mackay [Team leader, Inria, Senior Researcher, HDR]
- Theophanis Tsandilas [Inria, Researcher]
- Baptiste Caramiaux [CNRS, Researcher]

**Faculty Members**
- Joanna Mcgrenere [University of British Columbia and Inria Chair, from May 2018 until Jul 2018]
- Michel Beaudouin-Lafon [Univ Paris-Sud, Professor, HDR]
- Sarah Fdili Alaoui [Univ Paris-Sud, Assistant Professor]
- Cédric Fleury [Univ Paris-Sud, Assistant Professor]

**Post-Doctoral Fellows**
- Jessalyn Alvina [Inria, until May 2018]
- Benjamin Bressolette [Univ Paris-Sud, from Dec 2018]
- John Maccallum [Inria, until Nov 2018]
- Nolwenn Maudet [Inria, until Mar 2018]
- Andrew Webb [Inria]

**PhD Students**
- Dimitrios Christaras Papageorgiou [Univ Paris-Sud, from Oct 2018]
- Marianela Ciolfi Felice [Univ Paris-Sud]
- Carla Griggio [Inria]
- Per Carl Viktor Gustafsson [Univ Paris-Sud, from Oct 2018]
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- Shu-Yuan Hsueh [Univ Paris-Sud]
2. Overall Objectives

2.1. Overall Objectives

Interactive devices are everywhere: we wear them on our wrists and belts; we consult them from purses and pockets; we read them on the sofa and on the metro; we rely on them to control cars and appliances; and soon we will interact with them on living room walls and billboards in the city. Over the past 30 years, we have witnessed tremendous advances in both hardware and networking technology, which have revolutionized all aspects of our lives, not only business and industry, but also health, education and entertainment. Yet the ways in which we interact with these technologies remains mired in the 1980s. The graphical user interface (GUI), revolutionary at the time, has been pushed far past its limits. Originally designed to help secretaries
perform administrative tasks in a work setting, the GUI is now applied to every kind of device, for every kind of setting. While this may make sense for novice users, it forces expert users to use frustratingly inefficient and idiosyncratic tools that are neither powerful nor incrementally learnable.

ExSitu explores the limits of interaction — how extreme users interact with technology in extreme situations. Rather than beginning with novice users and adding complexity, we begin with expert users who already face extreme interaction requirements. We are particularly interested in creative professionals, artists and designers who rewrite the rules as they create new works, and scientists who seek to understand complex phenomena through creative exploration of large quantities of data. Studying these advanced users today will not only help us to anticipate the routine tasks of tomorrow, but to advance our understanding of interaction itself. Our goal is to advance our understanding of interaction as a phenomenon, with a corresponding paradigm shift in how we design, implement and use interactive systems. We have already made significant progress through our work on instrumental interaction and co-adaptive systems, and we hope to extend these into a foundation for the design of all interactive technology.

3. Research Program

3.1. Research Program

We characterize Extreme Situated Interaction as follows:

**Extreme users.** We study extreme users who make extreme demands on current technology. We know that human beings take advantage of the laws of physics to find creative new uses for physical objects. However, this level of adaptability is severely limited when manipulating digital objects. Even so, we find that creative professionals—artists, designers and scientists—often adapt interactive technology in novel and unexpected ways and find creative solutions. By studying these users, we hope to not only address the specific problems they face, but also to identify the underlying principles that will help us to reinvent virtual tools. We seek to shift the paradigm of interactive software, to establish the laws of interaction that significantly empower users and allow them to control their digital environment.

**Extreme situations.** We develop extreme environments that push the limits of today’s technology. We take as given that future developments will solve “practical” problems such as cost, reliability and performance and concentrate our efforts on interaction in and with such environments. This has been a successful strategy in the past: Personal computers only became prevalent after the invention of the desktop graphical user interface. Smartphones and tablets only became commercially successful after Apple cracked the problem of a usable touch-based interface for the iPhone and the iPad. Although wearable technologies, such as watches and glasses, are finally beginning to take off, we do not believe that they will create the major disruptions already caused by personal computers, smartphones and tablets. Instead, we believe that future disruptive technologies will include fully interactive paper and large interactive displays.

Our extensive experience with the Digiscope WILD and WILDER platforms places us in a unique position to understand the principles of distributed interaction that extreme environments call for. We expect to integrate, at a fundamental level, the collaborative capabilities that such environments afford. Indeed almost all of our activities in both the digital and the physical world take place within a complex web of human relationships. Current systems only support, at best, passive sharing of information, e.g., through the distribution of independent copies. Our goal is to support active collaboration, in which multiple users are actively engaged in the lifecycle of digital artifacts.

**Extreme design.** We explore novel approaches to the design of interactive systems, with particular emphasis on extreme users in extreme environments. Our goal is to empower creative professionals, allowing them to act as both designers and developers throughout the design process. Extreme design affects every stage, from requirements definition, to early prototyping and design exploration, to implementation, to adaptation and appropriation by end users. We hope to push the limits of participatory design to actively support creativity
at all stages of the design lifecycle. Extreme design does not stop with purely digital artifacts. The advent of
digital fabrication tools and FabLabs has significantly lowered the cost of making physical objects interactive.
Creative professionals now create hybrid interactive objects that can be tuned to the user’s needs. Integrating
the design of physical objects into the software design process raises new challenges, with new methods and
skills to support this form of extreme prototyping.

Our overall approach is to identify a small number of specific projects, organized around four themes:
Creativity, Augmentation, Collaboration and Infrastructure. Specific projects may address multiple themes,
and different members of the group work together to advance these different topics.

4. Application Domains

4.1. Creative industries
We work closely with creative professionals in the arts and in design, including music composers, musicians,
and sound engineers; painters and illustrators; dancers and choreographers; theater groups; game designers;
graphic and industrial designers; and architects.

4.2. Scientific research
We work with creative professionals in the sciences and engineering, including neuroscientists and doctors;
programmers and statisticians; chemists and astrophysicists; and researchers in fluid mechanics.

5. Highlights of the Year

5.1. Highlights of the Year
5.1.1. Awards
- ANR ELEMENT project was accepted.
- CNRS PEPS project was accepted.
- ERC CREATIV was extended for a year.
- Wanyu Liu, Olivier Rioul, Joanna McGrenere, Wendy Mackay, and Michel Beaudouin- Lafon:
  Honorable Mention award at ACM CHI 2018 for “BIGFile: Bayesian Information Gain for Fast
  File Retrieval” [22]

6. New Software and Platforms

6.1. Platforms
6.1.1. WildOS
Participant: Michel Beaudouin-Lafon [correspondant].

WildOS is middleware designed to support applications that run in an interactive room, such as our WILD and
WILDER rooms, with various interaction resources, including a tiled wall display, a motion tracking system,
interactive tabletops, tablets, smartphones and custom-made or 3d printed interactive devices. The conceptual
model of WildOS is a platform, such as the WILD or WILDER room, that can be described as a set of devices
on which one or more applications can be run.
WildOS consists of a server running on a machine that has network access to all the machines involved in the platform, and a set of clients running on the various interaction resources, such as a display cluster or a tablet. Once WildOS is running, applications can be started and stopped and devices can be added to or removed from the platform.

WildOS relies on Web technologies, most notably Javascript and node.js, as well as node-webkit and HTML5. This makes it inherently portable (it is currently tested on Mac OS X and Linux). While applications can be developed only with these Web technologies, it is also possible to bridge to existing applications developed in other environments if they provide sufficient access for remote control. Sample applications include a web browser, an image viewer, a window manager, and the BrainTwister application developed in collaboration with neuroanatomists at NeuroSpin.

WildOS is used for several research projects at ExSitu and by other partners of the Digiscope project. It was also deployed on several of Google’s interactive rooms in Mountain View, Dublin and Paris. It is available under an Open Source licence at https://bitbucket.org/mblinsitu/wildos.

- ACM: H.5.2 [User Interfaces]: Graphical user interfaces (GUI)
- Software benefit: helps development of multisurface applications.
- OS/Middleware: Crossplatform
- Required library or software: node.js, node-webkit
- Programming language: Javascript

6.1.2. Unity Cluster

Participants: Cédric Fleury [correspondant], Olivier Gladin [SED-SAC].

Unity Cluster is middleware to distribute any Unity 3D (https://unity3d.com/) application on a cluster of computers that run in interactive rooms, such as our WILD and WILDER rooms, or immersive CA VES (Computer-Augmented Virtual Environments). Users can interact with the application with various interaction resources.

Unity Cluster provides an easy solution for running existing Unity 3D applications on any display that requires a rendering cluster with several computers. Unity Cluster is based on a master-slave architecture: The master computer runs the main application and the physical simulation as well as manages the input; the slave computers receive updates from the master and render small parts of the 3D scene. Unity Cluster manages data distribution and synchronization among the computers to obtain a consistent image on the entire wallsized display surface.

Unity Cluster can also deform the displayed images according to the user’s position in order to match the viewing frustum defined by the user’s head and the four corners of the screens. This respects the motion parallax of the 3D scene, giving users a better sense of depth.

Unity Cluster is composed of a set of C Sharp scripts that manage the network connection, data distribution, and the deformation of the viewing frustum. In order to distribute an existing application on the rendering cluster, all scripts must be embedded into a Unity package that is included in an existing Unity project.

- ACM: C.2.4 [Distributed Systems]: Distributed applications, I.3.7 [3D Graphics and Realism]: Virtual reality
- Software benefit: adapts existing Unity 3D application to a rendering cluster of an interactive room.
- OS/Middleware: Crossplatform
- Required library or software: Unity 3D
- Programming language: C Sharp

6.1.3. WILDER

Participants: Michel Beaudouin-Lafon [correspondant], Cédric Fleury, Olivier Gladin.
WILDER (Figure 1) is our second experimental ultra-high-resolution interactive environment, which follows the WILD platform developed in 2009. It features a wall-sized display with seventy-five 20” LCD screens, i.e. a 5m50 x 1m80 (18’ x 6’) wall displaying 14 400 x 4 800 = 69 million pixels, powered by a 10-computer cluster and two front-end computers. The platform also features a camera-based motion tracking system that lets users interact with the wall, as well as the surrounding space, with various mobile devices. The display uses a multitouch frame (the largest of its kind in the world) to make the entire wall touch sensitive.

WILDER was inaugurated in June, 2015. It is one of the ten platforms of the Digiscope Equipment of Excellence and, in combination with WILD and the other Digiscope rooms, provides a unique experimental environment for collaborative interaction.

In addition to using WILD and WILDER for our research, we have also developed software architectures and toolkits, such as WildOS and Unity Cluster, that enable developers to run applications on these multi-device, cluster-based systems.

7. New Results

7.1. Fundamentals of Interaction

Participants: Michel Beaudouin-Lafon [correspondant], Wendy Mackay, Cédric Fleury, Theophanis Tsandilas, Dimitrios Christaras Papageorgiou, Han Han, Germán Leiva, Nolwenn Maudet, Yujiro Okuya, Miguel Renom, Philip Tchernavskij, Andrew Webb.

In order to better understand fundamental aspects of interaction, ExSitu conducts in-depth observational studies and controlled experiments which contribute to theories and frameworks that unify our findings and help us generate new, advanced interaction techniques. Our theoretical work also leads us to deepen or re-analyze existing theories and methodologies in order to gain new insights.

Continuing our long-standing exploration of Fitts’ law, we demonstrated the dangers of confounding factors in Fitts’-like experimental designs and recommended how to avoid them [20]. Confounds come from the fact that traditional Fitts’-like experiments use geometric progressions of the two main factors (target distance $D$ and amplitude $W$) and aggregate data points per $ID = \log(1 + D/W)$. This typically leads to a strong confound between $D$ and $ID$, whereby an effect attributed to $ID$ may in fact be due solely to $D$. We showed evidence of published results where this confound led to the misinterpretation of experimental results, and proposed stochastic sampling of $D$ and $W$ as a technique to avoid such problems.
We also reviewed statistical methods for the analysis of user-elicited gestural vocabularies [16] and argued that current statistics for assessing agreement across participants are problematic. First, we showed that raw agreement rates disregard agreement that occurs by chance and do not reliably capture how participants distinguish among referents. Second, we explained why current recommendations on how to interpret agreement scores rely on incorrect assumptions. Third, we demonstrated that significance tests for comparing agreement rates, either within or between participants, yield large Type I error rates (> 40% for $\alpha = .05$). As alternatives, we presented agreement indices that are routinely used in inter-rater reliability studies. We discussed how to apply them to gesture elicitation studies. We also demonstrated how to use common resampling techniques to support statistical inference with interval estimates. We applied these methods to reanalyze and reinterpret the findings of four gesture elicitation studies. We also participated in an invited formal debate at ACM/CHI 2018 to discuss the issue of replicability in HCI experiments, specifically whether or not the community should adopt the TOP (Transparency and Openness) guidelines for data and code transparency, citation, experiment preregistration and replication of experiments.

In order to explore novel forms of interaction based on the concepts of interaction instruments and interactive substrates, we conducted several studies and developed prototypes in three main areas:

First, we challenged the notion of application as the main organizing principle of digital environments. Most of our current interactions with the digital world are mediated by applications that impose artificial limits on collaboration among users and distribution across devices, and the constantly changing procedures that disrupt everyday use. These limitations are due partly to the engineering principles of encapsulation and program-data separation, which highlight the needs for appropriate conceptual models of interaction [18]. We proposed new architectural principles [28], [17] that address these issues by considering interactions as first-class objects that can be dynamically created, added to and removed from an interactive system.

Second, we addressed the needs of designers and developers of interactive systems through a series of studies and prototypes. Current prototyping tools do not adequately support the early stages of design, nor the necessary communication between designers and developers. We created and evaluated VideoClipper and Montage [21], two tools that facilitate video prototyping for the early sketching of ideas. VideoClipper facilitates the planning and capturing of video brainstorming ideas and video prototypes, while Montage (fig. 2) uses chroma-keying to create more advanced video prototypes and facilitating their reuse in different contexts. We also created Enact (under submission), a prototyping tool that lets designers and developers work in the same environment to create novel touch-based interaction techniques. Germán Leiva, supervised by Michel Beaudouin-Lafon, successfully defended his Ph.D. thesis Interactive Prototyping of Interactions: From Throwaway Prototypes to Takeaway Prototyping [34] on this topic.
Figure 3. Pre-computed meshes of a rear-view mirror while modifying the right part: the user’s hand position ($P_{\text{hand}}$) determines the selected shape (left). A virtual car cockpit where the user modifies the rear-view mirror shape in real time, using haptic force feedback (right).

Third, in the context of Computer Aided Design (CAD), we explored solutions for modifying parametric CAD objects in an immersive virtual reality system. In particular, we developed ShapeGuide [14], a technique that lets users modify parameter values by directly pushing or pulling the surface of a CAD object (Figure 3). Including force feedback increases the precision of the users’ hand motions in the 3D space. In a controlled experiment, we compared ShapeGuide to a standard one-dimensional scroll technique to measure its added value for parametric CAD data modification on a simple industrial object. We also evaluated the effect of force feedback assistance on both techniques. We demonstrated that ShapeGuide is significantly faster and more efficient than the scroll technique. In addition, we showed that force feedback assistance enhances the precision of both techniques.

### 7.2. Human-Computer Partnerships

**Participants:** Wendy Mackay [correspondent], Baptiste Caramiaux, Téo Sanchez, Marianela Ciolfi Felice, Carla Griggio, Shu Yuan Hsueh, Wanyu Liu, John Maccallum, Nolwenn Maudet, Joanna Mcgrenere, Midas Nouwens, Andrew Webb.

ExSitu is interested in designing effective human-computer partnerships, in which expert users control their interaction with technology. Rather than treating the human users as the ‘input’ to a computer algorithm, we explore human-centered machine learning, where the goal is to use machine learning and other techniques to increase human capabilities. Much of human-computer interaction research focuses on measuring and improving productivity: our specific goal is to create what we call ‘co-adaptive systems’ that are discoverable, appropriable and expressive for the user.

The Bayesian Information Gain (BIG) project uses Bayesian Experimental Design, where the criterion is to maximize the information-theoretic concept of mutual information, also known as information gain (fig. 4-left). The resulting interactive system “runs experiments” on the user in order to maximize the information gain from the user’s next input and get to the user’s goal more efficiently. BIGnav applies BIG to multiscale navigation [7]. Rather than simply executing the navigation commands issued by the user, BIGnav interprets them to update its knowledge about the user’s intended target, and then computes a new view that maximizes the expected information gain provided by the user’s next input. This view is located such that, from the system’s perspective, the possible navigation commands are uniformly probable, to the extent possible. BIGFile [22] (ACM CHI Honorable Mention award) uses a similar approach for file navigation, with a split interface (fig. 4-right) that combines a classical area where users can navigate the file system as usual and an adaptive area with a set of shortcuts calculated with BIG. BIGnav and BIGFile create a novel form of human-computer partnership, where the computer challenges the user in order to extract more information from the user’s input, making interaction more efficient. We showed that both techniques are significantly faster...
(40% and more) than conventional navigation techniques. Wanyu Liu, supervised by Michel Beaudouin-Lafon, successfully defended her Ph.D. thesis *Information theory as a unified tool for understanding and designing human-computer interaction* [35] on this topic.

In the area of visualization, we studied the common challenge faced by domain experts when identifying and comparing patterns in time series data. While automatic measures exist to compute time series similarity, human intervention is often required to visually inspect these automatically generated results. In collaboration with the ILDA Inria team and Univ. Paris-Descartes, we studied how different visualization techniques affect similarity perception in EEG signals [12], [31]. Our goal was to understand if the time series results returned from automatic similarity measures are perceived in a similar manner, irrespective of the visualization technique; and if what people perceive as similar with each visualization aligns with different automatic measures and their similarity constraints. Overall, our work indicates that the choice of visualization affects which temporal patterns we consider to be similar, i.e., the notion of similarity in a time series is not visualization independent. This demonstrates the need for effective human-computer partnerships in which the computer complements, rather than replaces, human skills and expertise.

We began to explore *human-centred machine learning*, which takes advantage of *active machine learning* to facilitate personalization of an interactive system. We developed a gesture-based recognition system where the user iteratively provides instances and also answers the system’s queries. Our results demonstrated the phenomenon of co-adaptation between the human user and the system, which challenges the state of the art in conventional active learning. We further explored interactive reinforcement learning as a way to explore high-dimensional parametric space efficiently [24].

7.3. Creativity

**Participants:** Sarah Fdili Alaoui [correspondent], Marianela Ciolfi Felice, Carla Griggio, Shu Yuan Hsueh, Germán Leiva, John Maccallum, Wendy Mackay, Baptiste Caramiaux, Nolwenn Maudet, Joanna Mcgrenere, Midas Nouwens, Jean-Philippe Rivière, Nicolas Taffin, Philip Tchernavskij, Theophanis Tsandilas, Andrew Webb, Michael Wessely.

ExSitu is interested in understanding the work practices of creative professionals, particularly artists, designers, and scientists, who push the limits of interactive technology. We follow a multi-disciplinary participatory design approach, working with both expert and non-expert users in diverse creative contexts. We also create situations that cause users to reflect deeply on their activities in situ and collaborate to articulate new design problems.
We identified diverse strategies for recording choreographic fragments and, influenced by the concept of information substrates, designed Knotation [19], a mobile pen-based tool where choreographers sketch representations of their choreographic ideas and make them interactive (Figure 5). Subsequent studies showed that Knotation supports both dance-then-record and record-then-dance strategies. Marianela Ciolfi Felice, supervised by Wendy Mackay and Sarah Fdili Alaoui, successfully defended her Ph.D. thesis Supporting Expert Creative Practice on this topic [32].

Figure 5. A choreographer uses Knotation to specify and interact with the spatial and temporal layout of a piece.

We are also developing a Choreographer’s Workbench, a full-body interactive system that helps choreographers explore dance movements by linking previously recorded movement ideas and revealing their underlying relationships. The system emphasizes discoverability and appropriation of movement ideas, using feedforward to visualize movement characteristics. We studied how dancers learn complex expressive movements [23], and studied how variability during practice affects learning motor and timing skills [11]. We contributed to soma-based design, i.e. movement-based designs and design practices specifically engaging with aesthetics [13]. We also collaborated with Ircam on a tool that uses reinforcement learning to explore high-dimensional sound spaces [24]. Users enter likes and dislikes to guide navigation within the sound space, shifting from a parameter-based to a reward-based exploration strategy.

We also are interested in how makers transition between physical and digital designs. Makers often create both physical and digital prototypes to explore a design, taking advantage of the subtle feel of physical materials and the precision and power of digital models. We developed ShapeMe [25], a novel smart material that captures its own geometry as it is physically cut by an artist or designer. ShapeMe includes a software toolkit that lets its users generate customized, embeddable sensors that can accommodate various object shapes. As the designer works on a physical prototype, the toolkit streams the artist’s physical changes to its digital counterpart in a 3D CAD environment (Figure 6). We used a rapid, inexpensive and simple-to-manufacture inkjet printing technique to create embedded sensors. We successfully created a linear predictive model of the sensors’ lengths, and our empirical tests of ShapeMe showed an average accuracy of 2 to 3 mm. We further presented an application scenario for modeling multi-object constructions, such as architectural models, and 3D models consisting of multiple layers stacked one on top of each other.

We also presented Interactive Tangrami [29], a method for prototyping interactive physical interfaces from functional paper-folded building blocks (Tangramis). Interactive Tangrami can contain various sensor input and visual output capabilities. Our digital design tool lets makers design the shape and interactive behavior of custom user interfaces. The software manages the communication with the paper-folded blocks and streams the interaction data via the Open Sound protocol (OSC) to an application prototyping environment, such as MaxMSP. The building blocks are fabricated digitally with a rapid and inexpensive ink-jet printing method. Our systems allows to prototype physical user interfaces within minutes and without knowledge of the underlying technologies. Finally, we continued our work with Saarland University, TU Berlin and MIT on digitally fabricated directional screens [15]. Michael Wessely, supervised by Theophanis Tsandilas and Wendy
Figure 6. ShapeMe is a novel sensing technology that enables physical modeling with shape-aware material: (a) The maker cuts a foamcore piece to reshape the walls of a house model. The updated shape is captured by a grid of length-aware sensors and is communicated to 3D modeling software. (b) The makers digitally creates the pieces of the roof and then produces its physical model. (c) The maker explores variations of the roof by cutting its side with scissors, while its shape is continuously captured.

Mackay, successfully defended his Ph.D. thesis Fabricating Malleable Interaction-Aware Material [36] on these topics.

7.4. Collaboration

Participants: Cédric Fleury [correspondant], Michel Beaudouin-Lafon, Wendy Mackay, Carla Griggio, Yujiro Okuya.

ExSitu is interested in exploring new ways of supporting collaborative interaction and remote communication. We investigated how large interactive spaces such as wall-sized displays or immersive virtual reality systems can foster collaboration in both co-located and remote situations in the context of Digiscope (http://digiscope.fr). We also conducted in-depth studies to better understand communication through social networks.

Figure 7. Collaborative CAD data modification between a wall-sized display (left) and a CAVE system (right).

Remote users can have significantly different display and interaction capabilities, such as a wall-size display v.s. an immersive CAVE. We started to explore how such asymmetric interaction capabilities provide
interesting opportunities for new collaboration strategies. In particular, we developed a distributed architecture allowing the collaborative modifications of CAD data across heterogeneous platforms [27] and tested it between the EVE and WILDER platforms of Digiscope (CAVE vs. wall-sized touch display – Figure 7).

Remote collaboration across large interactive spaces also requires telepresence systems which support audio-video communication among users as they move in front of the display or inside of the immersive virtual reality system. We have added 3D audio to improve spatial awareness of remote users [26]: 3D audio lets us position a sound source for each remote participant at the virtual position occupied by this participant in the local space. When using video as well as audio, this lets us position the audio feed so that it is congruent with the position of the video feed.

Finally, we conducted an in-depth study of how users communicate via multiple social network apps that offer almost identical functionality. We studied how and why users distribute their contacts within their app ecosystem. We found that users appropriate the features and technical constraints of their apps to create idiosyncratic “communication places”, each with its own recursively defined membership rules, perceived purposes, and emotional connotations. Users also shift the boundaries of their communication places to accommodate changes in their contacts’ behavior, the dynamics of their relationships, and the restrictions of the technology. We argue that communication apps should support creating multiple “communication places” within the same app, relocating conversations across apps, and accessing functionality from other apps. Carla Griggio, supervised by Wendy Mackay, successfully defended her Ph.D. thesis Designing for Ecosystems of Communication Apps [33] on this topic.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. MoveIT – Modeling the Speed/Accuracy Trade-Off of Human Aimed Movement with the Tools of Information Theory

Type: Ph.D. grant  
Funding: DigiCosme Labex  
Duration: 2015-2018  
Coordinator: Olivier Rioul (Institut Mines Telecom)  
Partners: Univ. Paris-Sud, Inria, CNRS, Institut Mines-Telecom  
Inria contact: Michel Beaudouin-Lafon  
Abstract: The goal of this project is to conduct fundamental studies of aimed movements based on information theory. The project studies the interaction phenomena involved in pointing, in order to discover novel, more effective pointing techniques. This project funds Wanyu Liu, a joint Ph.D. student between the COMELEC and VIA groups at Institut Mines Telecom and ExSitu. Wanyu defended her thesis in November 2018 [35] and received an Honorable Mention award for her CHI 2018 paper [22].

8.1.2. An Augmented-Reality System for Collaborative Physical Modeling and Design

Type: Equipment  
Funding: STIC Paris-Saclay  
Duration: 2017-2018  
Coordinator: Theophanis Tsandilas  
Partners: Univ. Paris-Sud, Inria  
Inria contact: Theophanis Tsandilas
Abstract: The goal of the project is to develop an augmented-reality system to support collaboration over 3D models and enhance digital-fabrication approaches. It is a collaboration with the AVIZ group and provides funding (8k) for equipment.

8.1.3. *Le Plateau des Recherches Infinies*

Type: Equipment and subcontracting  
Funding: Learning Center Paris-Saclay  
Duration: 2017-2018  
Coordinator: Michel Beaudouin-Lafon  
Partners: Univ. Paris-Sud  
Inria contact: Michel Beaudouin-Lafon  
Abstract: The goal of this project (30k) is to create an interactive installation presenting the portraits of a hundred researchers from Université Paris-Saclay. It is a collaboration with portrait photographer Didier Goupy. The installation is designed to be exhibited in various sites of Université Paris-Saclay until it is permanently installed in the Learning Center of Université Paris-Saclay. This project supported Swati Swati, an intern, for two months over the summer. The project was presented at the Fête de la Science in October, 2018, and will be permanently exhibited in the future Learning Center of Université Paris-Saclay.

8.1.4. *Virtual Reality for Interacting with Building Information Model at Paris-Saclay*

Type: Equipment and human resources  
Funding: STIC Paris-Saclay  
Duration: 2018-2019  
Coordinator: Jean-Marc Vézien (LIMSI-CNRS)  
Partners: CNRS, Univ. Paris-Sud  
Inria contact: Cédric Fleury  
Abstract: The goal of this project is to develop interactive tools for BIM application in virtual reality using a user-centered design approach. The project will use as a case study the interior design of the Learning Center building on Paris-Saclay campus.

8.2. National Initiatives

8.2.1. ANR

ELEMENT: Enabling Learnability in Human Movement Interaction  
Type: Equipment and human resources  
Funding: ANR  
Duration: 2019-2022  
Coordinator: Baptiste Caramiaux, Sarah Fdili Alaoui, Wendy Mackay  
Partners: IRCAM, LIMSI  
Inria contact: Baptiste Caramiaux  
Abstract: The goal of this project is to foster innovation in multimodal interaction, from non-verbal communication to interaction with digital media/content in creative applications, specifically by addressing two critical issues: the design of learnable gestures and movements; and the development of interaction models that adapt to a variety of user’s expertise and facilitate human sensorimotor learning.
8.2.2. Investissements d’Avenir

8.2.2.1. Digiscope - Collaborative Interaction with Complex Data and Computation

Type: EQUIPEX (Equipement d’Excellence)
Duration: 2011-2019
Coordinator: Michel Beaudouin-Lafon
Partners: Université Paris-Saclay (coordinator), Université Paris-Sud, CNRS, CEA, Inria, Institut Mines-Telecom, CentraleSupelec, Université Versailles - Saint-Quentin, ENS Paris-Saclay, Maison de la Simulation
Overall budget: 22.5 Meuros, including 6.7 Meuros public funding from ANR
Abstract: The goal of the project is to create ten high-end interactive rooms interconnected by high-speed networks and audio-video facilities to support remote collaboration across interactive visualization environments. The equipment will be open to outside users and targets four main application areas: scientific discovery, product lifetime management, decision support for crisis management, and education and training. Digiscope includes the existing WILD room, and funded the WILDER room. ExSitu contributes its expertise in the design and evaluation of advanced interaction techniques and the development of distributed software architectures for interactive systems. All ten rooms and the telepresence network are operational. The project was successfully evaluated by an international jury in June, 2017.

8.3. European Initiatives

8.3.1. European Research Council (ERC)

8.3.1.1. Creating Human-Computer Partnerships

Program: ERC Advanced Grant
Project acronym: CREATIV
Project title: Creating Human-Computer Partnerships
Duration: June 2013 - May 2019
Coordinator: Wendy Mackay
Abstract: CREATIV explores how the concept of co-adaptation can revolutionize the design and use of interactive software. Co-adaptation is the parallel phenomenon in which users both adapt their behavior to the system’s constraints, learning its power and idiosyncrasies, and appropriate the system for their own needs, often using it in ways unintended by the system designer. A key insight in designing for co-adaptation is that we can encapsulate interactions and treat them as first class objects, called interaction instruments. This lets us focus on the specific characteristics of how human users express their intentions, both learning from and controlling the system. By making instruments co-adaptive, we can radically change how people use interactive systems, providing incrementally learnable paths that offer users greater expressive power and mastery of their technology. The initial goal of the CREATIV project is to fundamentally improve the learning and expressive capabilities of advanced users of creative software, offering significantly enhanced methods for expressing and exploring their ideas. The ultimate goal is to radically transform interactive systems for everyone by creating a powerful and flexible partnership between human users and interactive technology.

8.3.1.2. Unified Principles of Interaction

Program: ERC Advanced Grant
Project acronym: ONE
Project title: Unified Principles of Interaction
Duration: October 2016 - September 2020
Coordinator: Michel Beaudouin-Lafon
Abstract: The goal of ONE is to fundamentally re-think the basic principles and conceptual model of interactive systems to empower users by letting them appropriate their digital environment. The project addresses this challenge through three interleaved strands: empirical studies to better understand interaction in both the physical and digital worlds, theoretical work to create a conceptual model of interaction and interactive systems, and prototype development to test these principles and concepts in the lab and in the field. Drawing inspiration from physics, biology and psychology, the conceptual model combines substrates to manage digital information at various levels of abstraction and representation, instruments to manipulate substrates, and environments to organize substrates and instruments into digital workspaces.

8.3.2. Marie Sklodowska-Curie Actions

8.3.2.1. Enhancing Motion Interaction through Music Performance

Program: Marie Curie grant
Project acronym: MIM
Project title: Enhancing Motion Interaction
Duration: 2016 - 2018
Coordinator: Baptiste Caramiaux

Abstract: The goal of the project to enhance Human Motion–Computer Interaction by leveraging a multidisciplinary approach across experimental psychology, music technology and computational modelling. Firstly, the project examines skilled activities, in particular music performance, in order to understand fundamental cognitive and psychological aspects of control and expression in human motion. The project involves computational models of motor control and expressive variations built from music performance data collected during psychophysical studies. Secondly, the project broaches the implementation of these models in Digital Musical Instruments (DMI), thus creating a new type of digital instrument based on sensorimotor learning mechanisms. The resulting DMI is then assessed through a user study in which elements of exploration and engagement will be tested over several sessions. Therefore, the project contributes to two main uncharted research areas. Firstly it contributes to the fundamental understanding of sensorimotor learning processes by considering complex human motion, specifically motion in music performance. Secondly, it represents an original application of computational modelling by modelling expressive musical gestures and transferring these models to interactive systems.

8.4. International Initiatives

8.4.1. Inria International Labs

Inria@SiliconValley
Associate Team involved in the International Lab:

8.4.1.1. DECibel

Title: Discover, Express, Create – Interaction Technologies For Creative Collaboration
International Partner (Institution - Laboratory - Researcher):
University of California Berkeley (United States) - Electrical and Computer Engineering, Center for Magnetic Resonance Research - Bjoern Hartmann
Start year: 2016
The DECibel associated team includes Inria’s ExSitu and the CITRIS Connected Communities Initiative (CCI) at UC Berkeley. ExSitu explores extreme interaction, working with creative professionals and scientists who push the limits of technology to develop novel interactive technologies that offer new strategies for creative exploration. ExSitu’s research activities include: developing underlying theory (co-adaptive instruments and substrates), conducting empirical studies (participatory design with creative professionals), and implementing interactive systems (creativity support tools). The CITRIS Connected Communities Initiative investigates collaborative discovery and design through new technologies that enhance education, creative work, and public engagement. It develops interactive tools, techniques and materials for the rapid design and prototyping of novel interactive products, expertise sharing among designers, and citizen science investigations. DECibel will combine the strengths of these two groups to investigate novel tools and technologies that support Discovery, Expressivity, and Creativity.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

Joanne McGrenere, Professor at the University of British Columbia, Canada and Inria Chair, visited for two months, to work with Wendy Mackay, Carla Griggio, Jessalyn Alvina, Yi Zhang and John MacCallum.

8.5.1.1. Internships

Janin Koch, Ph.D. student from Aalto University, Finland, visited for three months to work with Wendy Mackay.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

- UIST 2018, ACM Symposium on User Interface Software and Technology, Publicity Co-Chair: Michael Wessely
- UIST 2018, ACM Symposium on User Interface Software and Technology, Video Preview Co-Chair: Carla Griggio
- UIST 2018, ACM Symposium on User Interface Software and Technology, Doctoral Symposium jury: Wendy Mackay
- CHI 2018 workshop “Rethinking Interaction: From instrumental interaction to human-computer partnerships Toolkits”, organizers: Wendy Mackay, Michel Beaudouin-Lafon
- Interaction 2018, Program Co-Chair: Nolwenn Maudet

9.1.2. Scientific Events Selection

9.1.2.1. Chair of Conference Program Committees

- I IHM 2018, Conférence Francophone d’Interaction Homme-Machine, Work-in-Progress (TeC) co-chair: Cédric Fleury

9.1.2.2. Member of the Conference Program Committees
9.1.3. Journal

9.1.3.1. Member of Editorial Boards

- PloS ONE: Baptiste Caramiaux (2018-)

9.1.3.2. Reviewer - Reviewing Activities

- TOCHI, Transactions on Computer Human Interaction, ACM: Baptiste Caramiaux
Frontiers in *Robotics and AI*, Virtual Environments section: Cédric Fleury

### 9.1.4. Invited Talks

- Univ. of California San Diego (UCSD), *Towards Unified Principles of Interaction*, March 2018: Michel Beaudouin-Lafon
- Univ. of California San Diego (UCSD), *Human-Computer Partnerships*, March 2018: Wendy Mackay
- Université de Zürich, *Human-Computer Partnerships*, 12 April 2018: Wendy Mackay
- Creativity Across Disciplines Symposium, Aarhus University, *Towards a Unified Theory of Interaction*, 5 April 2018: Wendy Mackay
- Rencontres Jeunes Chercheurs, RJHM, *Experiment Design in HCI*, July: Wendy Mackay
- GOTO Copenhagen, Keynote address, *Human-Computer Partnerships*, November 2018: Wendy Mackay
- Université de Poitiers, Techné Séminaire 1 *Technologie Numérique pour l’Education, Designing Interactive Systems*, 15 November 2018: Wendy Mackay
- Université de Poitiers, Techné Séminaire 2 *Technologie Numérique pour l’Education, Exploratory Experiment Design*: 15 November 2018: Wendy Mackay

### 9.1.5. Scientific Expertise

**International**

- ACM SIGCHI “Lifetime Service Award” committee member: Michel Beaudouin-Lafon

**National**

- Agence Nationale de la Recherche (ANR), Appel à projets jeunes chercheuses et jeunes chercheurs: Theophanis Tsandilas, reviewer
- ERC Generator program, Université de Lille: Michel Beaudouin-Lafon, external expert
- CNRS INS2I “Cellule ERC”: Michel Beaudouin-Lafon, member
9.1.6. Research Administration

Information Science and Technology (STIC) Department, Université Paris-Saclay: Michel Beaudouin-Lafon (chair since June 2018), Wendy Mackay (member)

Research division, Université Paris-Saclay: Michel Beaudouin-Lafon (advisor for Digital Sciences since June 2018)

Digiteo RTRA research network, Université Paris-Saclay: Michel Beaudouin-Lafon (director since June 2018)

STIC Doctoral School, Université Paris-Saclay: Michel Beaudouin-Lafon (adjunct director of pole 3 until May 2018)

CNRS INS2I, “Conseil Scientifique de l’Institut”: Michel Beaudouin-Lafon (member)

Telecom ParisTech, “Comité de la recherche”: Michel Beaudouin-Lafon (member)

Pôle Systematic, Working group on Information Systems: Michel Beaudouin-Lafon (member of steering committee)

Computer Science Department, Université Paris-Sud: Michel Beaudouin-Lafon (vice-President for research)

“Conseil de Laboratoire”, LRI: Wendy Mackay, Cédric Fleury (members)

“Conseil Scientifique”, LRI: Michel Beaudouin-Lafon (member)

CCSU, “Commission Consultative de Spécialistes de l’Université”, Université Paris-Sud: Michel Beaudouin-Lafon, Wendy Mackay (members)

“Commission Locaux”, LRI: Theophanis Tsandilas (member)

“Commission Scientifique”, Inria: Theophanis Tsandilas (member), since March 2017

“Comité de sélection, Professeur”, Université de Bordeaux: Michel Beaudouin-Lafon (president)

“Comité de sélection, Maître de Conférence”, Université Paris-Sud: Wendy Mackay

“Tenure review committee”, University of California, Irvine: Wendy Mackay

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence : Sarah Fdili Alaoui, Programmaton des interfaces interactives avancées, 22.5h, L3, Univ. Paris-Sud

International Masters: Theophanis Tsandilas, Probabilities and Statistics, 32h, M1, Univ. Paris-Saclay

HCID Masters: Sarah Fdili Alaoui, Business Development Labs, 30h, M1, Univ. Paris-Sud

HCID Masters: Sarah Fdili Alaoui, Innovation & Entrepreneurship thesis, 3h, M2, Univ. Paris-Sud

HCID Masters: Sarah Fdili Alaoui, Design Project, 36h, M1 et M2, Univ. Paris-Sud

HCID Masters: Michel Beaudouin-Lafon, Wendy Mackay, Fundamentals of Situated Interaction, 21 hrs, M1/M2, Univ. Paris-Sud

Interaction & HCID Masters: Sarah Fdili Alaoui, Stage en entreprise, 2h, M2, Univ. Paris-Sud

Interaction & HCID Masters: Sarah Fdili Alaoui, Creative Design, 27h, M1 et M2, Univ. Paris-Sud

Interaction & HCID Masters: Sarah Fdili Alaoui, Digital Fabrication, 13.5h, M1 et M2, Univ. Paris-Sud

Interaction & HCID Masters: Michel Beaudouin-Lafon, Fundamentals of Human-Computer Interaction, 21 hrs, M1/M2, Univ. Paris-Sud

Interaction & HCID Masters: Michel Beaudouin-Lafon & Cédric Fleury, Groupware and Collaborative Interaction, 31.5 hrs, M1/M2, Univ. Paris-Sud
Interaction & HCID Masters: Wendy Mackay, *Career Seminar* 6 hrs, M2, Univ. Paris-Sud
Interaction & HCID Masters: Wendy Mackay, *Design of Interactive Systems*, 21 hrs, M1/M2, Univ. Paris-Sud
Polytech: Sarah Fdili Alaoui, *Graphisme et Visualisation*, 18h, “Apprentis” 5th year, Univ. Paris-Sud
Polytech: Cédric Fleury, *Option Réalité Virtuelle*, 56 hrs, 5th year, Univ. Paris-Sud

9.2.2. Supervision

PhD students

PhD: Michael Wessely, *Sketching and Physical Prototyping for Creative Fabrication Design*, Université Paris-Saclay, 13 December 2018. Advisors: Theophanis Tsandilas & Wendy Mackay
PhD in progress: Yujiro Okuya, *Sensorimotor interface for Collaborative Virtual Environments based on heterogeneous interactive devices: application to industrial design*, October 2015. Advisors: Patrick Bourdot (LIMSI-CNRS) & Cédric Fleury
PhD in progress: Yiran Zhang, *Telepresence for remote and heterogeneous Collaborative Virtual Environments*, October 2017. Advisors: Patrick Bourdot (LIMSI-CNRS) & Cédric Fleury

PhD in progress: Han Han, *Participatory design of digital environments based on interaction substrates*, October 2018. Advisor: Michel Beaudouin-Lafon


**Masters students**

Téo Sanchez, ENS, Sorbonne Université, “Gesture Interaction with Active Machine Learners”: Baptiste Caramiaux

Miguel Renom, “Transfer of tool-based skills from physical to digital tools”: Michel Beaudouin-Lafon

Dimitrios Christaras Papageorgiou, “Prototype of an environment based on information substrates and digital instruments”: Michel Beaudouin-Lafon

Tong Xue, “Analysis of information substrates and digital instruments in existing interactive software”: Michel Beaudouin-Lafon

Viktor Gustafsson, “Narrative Substrates for Interactive Video Games”: Wendy Mackay

Yi Zhang, “Situated Breakdowns in Video-Mediated Communication”: Wendy Mackay

Wuji Geng, “Interaction Museum Design”: Wendy Mackay

Krishnan Chandran, “Collocated Collaboration over Augmented Reality Models”: Theophanis Tsandilas and Cédric Fleury

### 9.2.3. Juries

**PhD theses**

- Emaline Brulé, Télécom ParisTech (advisor: Annie Gentes): Wendy Mackay, reporter
- Julien Gori, Télécom ParisTech (advisor: Olivier Rioul): Michel Beaudouin-Lafon, invited
- Benjamen Bressolette, Centrale Marseille (advisor: Richard Kronland-Martinet): Michel Beaudouin-Lafon, examiner

**Habilitations**

- Marcos Serrano, Université de Toulouse, November 2018: Michel Beaudouin-Lafon, reviewer
- Eric Lecolinet, Télécom ParisTech, December 2018: Michel Beaudouin-Lafon, examiner

### 9.3. Popularization

#### 9.3.1. Articles and contents

- Panel at “La Fabrique de la Danse”, Centre 104, Paris, 5 Avril 2018: Baptiste Caramiaux (panel member)

#### 9.3.2. Interventions

- Le Plateau des Recherches Infinies: art-science project with photographer Didier Goupy presenting the portraits of 100 researchers of Université Paris-Saclay. Fête de la Science, Gif-sur-Yvette, October 2018
- Workshop on “Rapid Prototyping with Interactive Materials”, Fab14, Toulouse, July 2018: Michael Wessely

10. Bibliography

Major publications by the team in recent years


Publications of the year

Articles in International Peer-Reviewed Journals


International Conferences with Proceedings


Conferences without Proceedings


Research Reports


References in notes

[32] M. C. Felice. Supporting Expert Creative Practice, Université Paris-Saclay, Orsay, France, December 2018

[33] C. Grigio. Designing for Ecosystems of Communication Apps, Université Paris-Saclay, Orsay, France, December 2018

[34] G. Leiva. Interactive Prototyping of Interactions: From Throwaway Prototypes to Takeaway Prototyping, Université Paris-Saclay, Orsay, France, December 2018

[35] W. Liu. Information theory as a unified tool for understanding and designing human-computer interaction, Université Paris-Saclay, Orsay, France, November 2018

[36] M. Wessely. Fabricating Malleable Interaction-Aware Material, Université Paris-Saclay, Orsay, France, December 2018