Activity Report 2019

Project-Team LOKI

technology & knowledge for interaction

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Creation of the Project-Team: 2019 July 01

Keywords:

    <u>**Computer Science and Digital Science:**</u>

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        A5.1.2. - Evaluation of interactive systems
        A5.1.3. - Haptic interfaces
        A5.1.4. - Brain-computer interfaces, physiological computing
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1. Team, Visitors, External Collaborators

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    Mathieu Nancel [Inria, Researcher]
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    Edward Lank [Inria, International Chair from Nov 2019 & Professor at University of Waterloo]

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Philippe Schmid [Inria, from Mar 2019 until Sep 2019]
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Julie Jonas [Inria]

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Edward Lank [Professor at University of Waterloo, from Aug 2019 until Oct 2019]

2. Overall Objectives

2.1. Introduction

Human-Computer Interaction (HCI) is a constantly moving field [38]. Changes in computing technologies extend their possible uses and modify the conditions of existing ones. People also adapt to new technologies and adapt them to their own needs [42]. Different problems and opportunities thus regularly appear that require to be addressed from both the user and the machine perspective, to understand and account for the tight coupling between human factors and interactive technologies. Our vision is to link together these two essential elements: *Knowledge & Technology for Interaction*.

2.2. Knowledge for Interaction

In the early 1960s, when computers were scarce, expensive, bulky, and formal-scheduled machines used for automatic computations, ENGELBART saw their potential as personal interactive resources. He saw them as *tools* we would purposefully use to carry out particular tasks and that would empower people by supporting intelligent use [35]. Others at the same time were seeing computers differently, as *partners*, intelligent entities to whom we would delegate tasks. These two visions still constitute the roots of today's predominant HCI paradigms, *use* and *delegation*. In the delegation approach, a lot of effort has been made to support oral, written and non-verbal forms of human-computer communication, and to analyze and predict human behavior. But the inconsistency and ambiguity of human beings, and the variety and complexity of contexts, make these tasks very difficult [46] and the machine is thus the center of interest.

2.2.1. *Computers as tools*

Our focus is not in what machines can understand or do by themselves, but in what people can do with them. We do not reject the delegation paradigm but clearly favor the one of tool use, aiming for systems that support intelligent use rather than intelligent systems. And as the frontier is getting thinner, ***one of our goals is to better understand what it takes for an interactive system to be perceived as a tool or a partner, and how the two paradigms can be combined for the best benefit of the user.***

2.2.2. *Empowering tools*

The ability provided by interactive tools to create and control complex transformations in real-time can support intellectual and creative processes in unusual but powerful ways. But mastering powerful tools is not simple and immediate, it requires learning and practice. ***Our research in HCI should not just focus on novice or highly proficient users, it should also care about intermediate ones willing to devote time and effort to develop new skills, be it for work or leisure.***

2.2.3. *Transparent tools*

Technology is most empowering when it is transparent: invisible in effect, it does not get in your way but lets you focus on the task. HEIDEGGER characterized this unobtruded relation to things with the term *zuhanden* (*ready-to-hand*). Transparency of interaction is not best achieved with tools mimicking human capabilities, but with tools taking full advantage of them given the context and task. For instance, the transparency of driving a car "*is not achieved by having a car communicate like a person, but by providing the right coupling between the driver and action in the relevant domain (motion down the road)*" [49]. Our actions towards the digital world need to be digitized and we must receive proper feedback in return. But input and output technologies pose somewhat inevitable constraints while the number, diversity, and dynamicity of digital objects call for more and more sophisticated perception-action couplings for increasingly complex tasks. ***We want to study the means currently available for perception and action in the digital world: Do they leverage our perceptual and control skills? Do they support the right level of coupling for transparent use? Can we improve them or design more suitable ones?***

2.3. Technology for Interaction

Studying the *interactive phenomena* described above is one of the pillars of HCI research, in order to understand, model and ultimately improve them. Yet, we have to make those phenomena happen, to make them possible and reproducible, be it for further research or for their diffusion [37]. However, because of the high viscosity and the lack of openness of actual systems, this requires considerable efforts in designing, engineering, implementing and hacking hardware and software interactive artifacts. This is what we call "*The Iceberg of HCI Research*", of which the hidden part supports the design and study of new artifacts, but also informs their creation process.

2.3.1. *"Designeering Interaction"*

Both parts of this iceberg are strongly influencing each other: The design of interaction techniques (the visible top) informs on the capabilities and limitations of the platform and the software being used (the hidden bottom), giving insights into what could be done to improve them. On the other hand, new architectures and software tools open the way to new designs, by giving the necessary bricks to build with [39]. These bricks define the adjacent possible of interactive technology, the set of what could be designed by assembling the parts in new ways. Exploring ideas that lie outside of the adjacent possible require the necessary technological evolutions to be addressed first. This is a slow and gradual but uncertain process, which helps to explore and fill a number of gaps in our research field but can also lead to deadlocks. ***We want to better understand and master this process—i. e., analyzing the adjacent possible of HCI technology and methods—and introduce tools to support and extend it. This could help to make technology better suited to the exploration of the fundamentals of interaction, and to their integration into real systems, a way to ultimately improve interactive systems to be empowering tools.***

2.3.2. *Computers vs Interactive Systems*

In fact, today's interactive systems—e. g., desktop computers, mobile devices—share very similar layered architectures inherited from the first personal computers of the 1970s. This abstraction of resources provides developers with standard components (UI widgets) and high-level input events (mouse and keyboard) that obviously ease the development of common user interfaces for predictable and well-defined tasks and users' behaviors. But it does not favor the implementation of non-standard interaction techniques that could be better adapted to more particular contexts, to expressive and creative uses. Those often require to go deeper into the system layers, and to hack them until getting access to the required functionalities and/or data, which implies switching between programming paradigms and/or languages.

And these limitations are even more pervading as interactive systems have changed deeply in the last 20 years. They are no longer limited to a simple desktop or laptop computer with a display, a keyboard and a mouse. They are becoming more and more distributed and pervasive (e. g., mobile devices, Internet of Things). They are changing dynamically with recombinations of hardware and software (e. g., transition between multiple

devices, modular interactive platforms for collaborative use). Systems are moving "out of the box" with Augmented Reality, and users are going " inside of the box" with Virtual Reality. This is obviously raising new challenges in terms of human factors, usability and design, but it also deeply questions actual architectures.

2.3.3. The Interaction Machine

We believe that promoting digital devices to ***empowering tools*** requires ***better fundamental knowledge about interaction phenomena*** AND to ***revisit the architecture of interactive systems*** in order to support this knowledge. By following a comprehensive systems approach—encompassing human factors, hardware elements, and all software layers above—we want to define the founding principles of an *Interaction Machine*:

- a set of hardware and software requirements with associated specifications for interactive systems to be tailored to interaction by leveraging human skills;

- one or several implementations to demonstrate and validate the concept and the specifications in multiple contexts;

- guidelines and tools for designing and implementing interactive systems, based on these specifications and implementations.

To reach this goal, we will adopt an opportunistic and iterative strategy guided by the *designeering* approach, where the engineering aspect will be fueled by the interaction design and study aspect. We will address several fundamental problems of interaction related to our vision of "empowering tools", which, in combination with state-of-the-art solutions, will instruct us on the requirements for the solutions to be supported in an interactive system. This consists in reifying the concept of the Interaction Machine into multiple contexts and for multiple problems, before converging towards a more unified definition of "what is an interactive system", the ultimate Interaction Machine, which constitutes the main scientific and engineering challenge of our project.

3. Research Program

3.1. Introduction

Interaction is by nature a dynamic phenomenon that takes place between interactive systems and their users. Redesigning interactive systems to better account for interaction requires fine understanding of these dynamics from the user side so as to better handle them from the system side. In fact, layers of actual interactive systems abstract hardware and system resources from a system and programing perspective. Following our Interaction Machine concept, we are reconsidering these architectures from the user's perspective, through different *levels of dynamics of interaction* (see Figure 1).

Considering phenomena that occur at each of these levels as well as their relationships will help us to acquire the necessary knowledge (Empowering Tools) and technological bricks (Interaction Machine) to reconcile the way interactive systems are designed and engineered with human abilities. Although our strategy is to investigate issues and address challenges for all of the three levels, our immediate priority is to focus on micro-dynamics since it concerns very fundamental knowledge about interaction and relates to very low-level parts of interactive systems, which is likely to influence our future research and developments at the other levels.

3.2. Micro-Dynamics

Micro-dynamics involve low-level phenomena and human abilities which are related to short time/instantness and to perception-action coupling in interaction, when the user has almost no control or consciousness of the action once it has been started. From a system perspective, it has implications mostly on input and output (I/O) management.
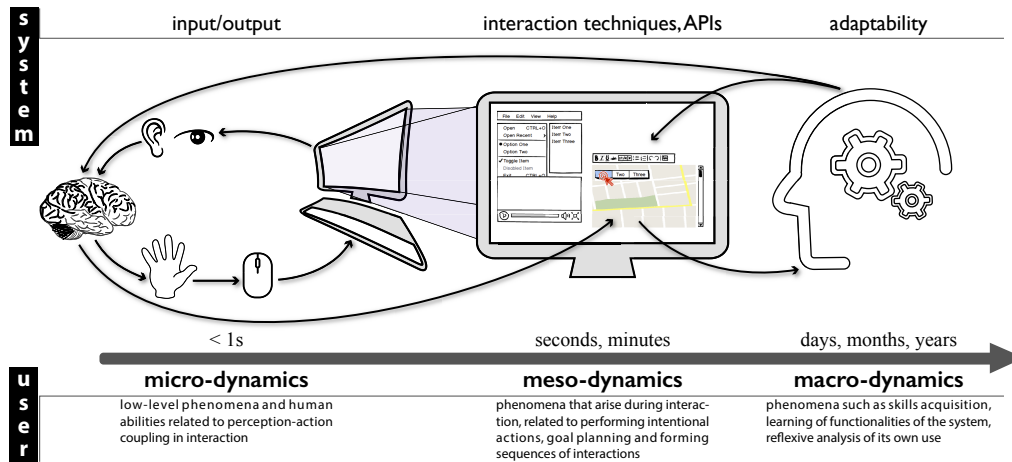
Figure 1. Levels of dynamics of interaction.

3.2.1. *Transfer functions design and latency management*

We have developed a recognized expertise in the characterization and the design of *transfer functions* [34], [45], i. e., the algorithmic transformations of raw user input for system use. Ideally, transfer functions should match the interaction context. Yet the question of how to maximize one or more criteria in a given context remains an open one, and on-demand adaptation is difficult because transfer functions are usually implemented at the lowest possible level to avoid latency. Latency has indeed long been known as a determinant of human performance in interactive systems [41] and recently regained attention with touch interactions [40]. These two problems require cross examination to improve performance with interactive systems: Latency can be a confounding factor when evaluating the effectiveness of transfer functions, and transfer functions can also include algorithms to compensate for latency.

We have recently proposed new cheap but robust methods for the measurement of end-to-end latency [2] and are currently working on compensation methods and the evaluation of their perceived side effects. Our goal is then to automatically adapt the transfer function to individual users and contexts of use while reducing latency in order to support stable and appropriate control. To achieve this, we will investigate combinations of low-level (embedded) and high-level (application) ways to take user capabilities and task characteristics into account and reduce or compensate for latency in different contexts, e. g., using a mouse or a touchpad, a touch-screen, an optical finger navigation device or a brain-computer interface. From an engineering perspective, this knowledge on low-level human factors will help us to rethink and redesign the I/O loop of interactive systems in order to better account for them and achieve more adapted and adaptable perception-action coupling.

3.2.2. *Tactile feedback & haptic perception*

We are also concerned with the physicality of human-computer interaction, with a focus on haptic perception and related technologies. For instance, when interacting with virtual objects such as software buttons on a touch surface, the user cannot feel the click sensation as with physical buttons. The tight coupling between how we perceive and how we manipulate objects is then essentially broken although this is instrumental for efficient direct manipulation. We have addressed this issue in multiple contexts by designing, implementing and evaluating novel applications of tactile feedback [5].

In comparison with many other modalities, one difficulty with tactile feedback is its diversity. It groups sensations of forces, vibrations, friction, or deformation. Although this is a richness, it also raises usability and

technological challenges since each kind of haptic stimulation requires different kinds of actuators with their own parameters and thresholds. And results from one are hardly applicable to others. On a "knowledge" point of view, we want to better understand and empirically classify haptic variables and the kind of information they can represent (continuous, ordinal, nominal), their resolution, and their applicability to various contexts. From the "technology" perspective, we want to develop tools to inform and ease the design of haptic interactions taking best advantage of the different technologies in a consistent and transparent way.

3.3. Meso-Dynamics

Meso-dynamics relate to phenomena that arise during interaction, on a longer but still short time-scale. For users, it is related to performing intentional actions, to goal planning and tools selection, and to forming sequences of interactions based on a known set of rules or instructions. From the system perspective, it relates to how possible actions are exposed to the user and how they have to be executed (i. e., interaction techniques). It also has implication on the tools for designing and implementing those techniques (programming languages and APIs).

3.3.1. *Interaction bandwidth and vocabulary*

Interactive systems and their applications have an always-increasing number of available features and commands due to, e. g., the large amount of data to manipulate, increasing power and number of functionalities, or multiple contexts of use.

On the input side, we want to augment the *interaction bandwidth* between the user and the system in order to cope with this increasing complexity. In fact, most input devices capture only a few of the movements and actions the human body is capable of. Our arms and hands for instance have many degrees of freedom that are not fully exploited in common interfaces. We have recently designed new technologies to improve expressibility such as a bendable digitizer pen [36], or reliable technology for studying the benefits of finger identification on multi-touch interfaces [4].

On the output side, we want to expand users' *interaction vocabulary*. All of the features and commands of a system can not be displayed on screen at the same time and lots of *advanced* features are by default hidden to the users (e. g., hotkeys) or buried in deep hierarchies of command-triggering systems (e. g., menus). As a result, users tend to use only a subset of all the tools the system actually offers [44]. We will study how to help them to broaden their knowledge of available functions.

Through this "opportunistic" exploration of alternative and more expressive input methods and interaction techniques, we will particularly focus on the necessary technological requirements to integrate them into interactive systems, in relation with our redesign of the I/O stack at the micro-dynamics level.

3.3.2. *Spatial and temporal continuity in interaction*

At a higher-level, we will investigate how more expressive interaction techniques affect users' strategies when performing sequences of elementary actions and tasks. More generally, we will explore the "*continuity*" in interaction. Interactive systems have moved from one computer to multiple connected interactive devices (computer, tablets, phones, watches, etc.) that could also be augmented through a Mixed-Reality paradigm. This distribution of interaction raises new challenges from both usability and engineering perspectives that we clearly have to consider in our main objective of revisiting interactive systems [43]. It involves the simultaneous use of multiple devices and also the changes in the role of devices according to the location, the time, the task, and contexts of use: a tablet device can be used as the main device while traveling, and it becomes an input device or a secondary monitor for continuing the same task once in the office; a smart-watch can be used as a standalone device to send messages, but also as a remote controller for a wall-sized display. One challenge is then to design interaction techniques that support seamless and smooth transitions during these spatial and temporal changes of the system in order to maintain the continuity of uses and tasks, and how to integrate these principles in future interactive systems.

3.3.3. *Expressive tools for prototyping, studying, and programming interaction*

Current systems suffer from engineering issues that keep constraining and influencing how interaction is thought, designed, and implemented. Addressing the challenges we presented in this section and making the solutions possible require extended expressiveness, and researchers and designers must either wait for the proper toolkits to appear, or "hack" existing interaction frameworks, often bypassing existing mechanisms. For instance, numerous usability problems in existing interfaces stem from a common cause: the lack, or untimely discarding, of relevant information about how events are propagated and how changes come to occur in interactive environments. On top of our redesign of the I/O loop of interactive systems, we will investigate how to facilitate access to that information and also promote a more grounded and expressive way to describe and exploit input-to-output chains of events at every system level. We want to provide finer granularity and better-described connections between the *causes* of changes (e.g. input events and system triggers), their *context* (e.g. system and application states), their *consequences* (e.g. interface and data updates), and their *timing* [8]. More generally, a central theme of our Interaction Machine vision is to promote interaction as a first-class object of the system [33], and we will study alternative and better-adapted technologies for designing and programming interaction, such as we did recently to ease the prototyping of Digital Musical Instruments [1] or the programming of animations in graphical interfaces [10]. Ultimately, we want to propose a unified model of hardware and software scaffolding for interaction that will contribute to the design of our Interaction Machine.

3.4. Macro-Dynamics

Macro-dynamics involve longer-term phenomena such as skills acquisition, learning of functionalities of the system, reflexive analysis of its own use (e. g., when the user has to face novel or unexpected situations which require high-level of knowledge of the system and its functioning). From the system perspective, it implies to better support cross-application and cross-platform mechanisms so as to favor skill transfer. It also requires to improve the instrumentation and high-level logging capabilities to favor reflexive use, as well as flexibility and adaptability for users to be able to finely tune and shape their tools.

We want to move away from the usual binary distinction between "novices" and "experts" [3] and explore means to promote and assist digital skill acquisition in a more progressive fashion. Indeed, users have a permanent need to adapt their skills to the constant and rapid evolution of the tasks and activities they carry on a computer system, but also the changes in the software tools they use [47]. Software strikingly lacks powerful means of acquiring and developing these skills [3], forcing users to mostly rely on outside support (e. g., being guided by a knowledgeable person, following online tutorials of varying quality). As a result, users tend to rely on a surprisingly limited interaction vocabulary, or *make-do* with sub-optimal routines and tools [48]. Ultimately, the user should be able to master the interactive system to form durable and stabilized practices that would eventually become *automatic* and reduce the mental and physical efforts, making their interaction *transparent*.

In our previous work, we identified the fundamental factors influencing expertise development in graphical user interfaces, and created a conceptual framework that characterizes users' performance improvement with UIs [7], [3]. We designed and evaluated new command selection and learning methods to leverage user's digital skill development with user interfaces, on both desktop [6] and touch-based computers.

We are now interested in broader means to support the analytic use of computing tools:

- *to foster understanding of interactive systems.* As the digital world makes the shift to more and more complex systems driven by machine learning algorithms, we increasingly lose our comprehension of which process caused the system to respond in one way rather than another. We will study how novel interactive visualizations can help reveal and expose the "intelligence" behind, in ways that people better master their complexity.

- *to foster reflexion on interaction.* We will study how we can foster users' reflexion on their own interaction in order to encourage them to acquire novel digital skills. We will build real-time and off-line software for monitoring how user's ongoing activity is conducted at an application and system

level. We will develop augmented feedbacks and interactive history visualization tools that will offer contextual visualizations to help users to better understand and share their activity, compare their actions to that of others, and discover possible improvement.

- *to optimize skill-transfer and tool re-appropriation.* The rapid evolution of new technologies has drastically increased the frequency at which systems are updated, often requiring to relearn everything from scratch. We will explore how we can minimize the cost of having to appropriate an interactive tool by helping users to capitalize on their existing skills.

We plan to explore these questions as well as the use of such aids in several contexts like web-based, mobile, or BCI-based applications. Although, a core aspect of this work will be to design systems and interaction techniques that will be as little platform-specific as possible, in order to better support skill transfer. Following our Interaction Machine vision, this will lead us to rethink how interactive systems have to be engineered so that they can offer better instrumentation, higher adaptability, and fewer separation between applications and tasks in order to support reuse and skill transfer.

4. Application Domains

4.1. Application Domains

Loki works on fundamental and technological aspects of Human-Computer Interaction that can be applied to diverse application domains.

Our 2019 research involved desktop, augmented reality, touch-based, haptics, and BCI interfaces with notable applications to medicine (analysis of fine motor control for patients with Parkinson disease), digital humanities (interpretation of handwritten historical documents), as well as creativity support tools (production of illustrations, design of Digital Musical Instruments). Our technical work also contributes to the more general application domains of software engineering and systems' design.

5. Highlights of the Year

5.1. Highlights of the Year

Géry Casiez and Mathieu Nancel received a very selective Google Faculty Research Award for their project "Real-time Latency Measure and Compensation".

Mathieu Nancel contributed to the writing of the new NF Z71-300 French keyboard standard, and spoke at the official launch event in April 2019 at the National Assembly.

5.1.1. *Personnel*

Edward Lank joined Loki in October as part of the Inria International Chair program and will spend more than 50% of his time with us until 2023.

5.1.2. *Awards*

Best paper award from the ACM EICS conference to the paper "Polyphony: Programming Interfaces and Interactions with the Entity-Component-System Model", from T. Raffaillac & S. Huot .

Best paper award from the Francophone Conference on Human-Computer Interaction (IHM) to the paper "Reducing Error Aversion to Support Novice-to-Expert Transitions with FastTap", from A. Goguey, S. Malacria, A. Cockburn & C. Gutwin .

BEST PAPERS AWARDS:

[22]

T. RAFFAILLAC, S. HUOT. *Polyphony: Programming Interfaces and Interactions with the Entity-Component-System Model*, in "EICS 2019 - 11th ACM SIGCHI Symposium on Engineering Interactive Computing Systems", Valencia, Spain, June 2019, vol. 3 [*DOI :* 10.1145/3331150], https://hal.inria.fr/hal-02147180

[25]

A. GOGUEY, S. MALACRIA, A. COCKBURN, C. GUTWIN. *Reducing Error Aversion to Support Novice-to-Expert Transitions with FastTap*, in "Actes de la 31e conférence francophone sur l'Interaction Homme-Machine (IHM 2019)", Grenoble, France, ACM, 2019, pp. 1:1-10 [*DOI :* 10.1145/3366550.3372247], https://hal.archives-ouvertes.fr/hal-02381584

6. New Software and Platforms

6.1. Polyphony

KEYWORDS: Human Computer Interaction - Toolkit - Engineering of Interactive Systems

FUNCTIONAL DESCRIPTION: Polyphony is an experimental toolkit demonstrating the use of Entity-Component-System (ECS) to design Graphical User Interfaces (GUI). It also extends the original ECS model to support advanced interfaces.

NEWS OF THE YEAR: Design and implementation of a first version of the toolkit and associated examples as a proof of concept.

- Participants: Thibault Raffaillac and Stéphane Huot
- Contact: Stéphane Huot
- Publications: Applying the Entity-Component-System Model to Interaction Programming - Polyphony: Programming Interfaces and Interactions with the Entity-Component-System Model
- URL: https://gitlab.inria.fr/Loki/PolyphonyECS

6.2. Esquisse

KEYWORDS: Vector graphics - 3D interaction - Human Computer Interaction

SCIENTIFIC DESCRIPTION: Trace figures are contour drawings of people and objects that capture the essence of scenes without the visual noise of photos or other visual representations. Their focus and clarity make them ideal representations to illustrate designs or interaction techniques. In practice, creating those figures is a tedious task requiring advanced skills, even when creating the figures by tracing outlines based on photos. To mediate the process of creating trace figures, we introduce the open-source tool Esquisse. Informed by our taxonomy of 124 trace figures, Esquisse provides an innovative 3D model staging workflow, with specific interaction techniques that facilitate 3D staging through kinematic manipulation, anchor points and posture tracking. Our rendering algorithm (including stroboscopic rendering effects) creates vector-based trace figures of 3D scenes. We validated Esquisse with an experiment where participants created trace figures illustrating interaction techniques, and results show that participants quickly managed to use and appropriate the tool.

FUNCTIONAL DESCRIPTION: Esquisse is an add-on for Blender that can be used to rapidly produce trace figures. It relies on a 3D model staging workflow, with specific interaction techniques that facilitate the staging through kinematic manipulation, anchor points and posture tracking. Staged 3D scenes can be exported to SVG thanks to Esquisse's dedicated rendering algorithm.

NEWS OF THE YEAR: First version of Esquisse, implementing both staging and vector rendering.

- Contact: Sylvain Malacria
- Publication: Esquisse: Using 3D Models Staging to Facilitate the Creation of Vector-based Trace Figures
- URL: https://github.com/LokiResearch/Esquisse

6.3. RayCursor

Source code for the pointing technique RayCursor

KEYWORDS: Virtual reality - Interaction technique

FUNCTIONAL DESCRIPTION: This is a Unity Project containing the source code and prefab for the pointing technique RayCursor to be easily integrated in other Unity Projects.

- Contact: Géry Casiez
- Publications: RayCursor: a 3D Pointing Facilitation Technique based on Raycasting - Improving Raycasting using Proximity Selection and Filtering
- URL: http://ns.inria.fr/loki/raycursor/

7. New Results

7.1. Introduction

According to our research program, in the next two to five years, we will study dynamics of interaction along three levels depending on interaction time scale and related user's perception and behavior: *Micro-dynamics*, *Meso-dynamics*, and *Macro-dynamics*. Considering phenomena that occur at each of these levels as well as their relationships will help us to acquire the necessary knowledge (Empowering Tools) and technological bricks (Interaction Machine) to reconcile the way interactive systems are designed and engineered with human abilities. Our strategy is to investigate issues and address challenges for all of the three levels of dynamics. Last year we focused on micro-dynamics since it concerns very fundamental knowledge about interaction and relates to very low-level parts of interactive systems. In 2019 we were able to build upon those results (micro), but also to enlarge the scope of our studies within larger interaction time scales, especially at the meso-dynamic level. Some of these results have also contributed to our objective of defining the basic principles of an Interaction Machine.

7.2. Micro-dynamics

Participants: Géry Casiez [contact person], Sylvain Malacria, Mathieu Nancel, Thomas Pietrzak.

7.2.1. *Latency & Transfer functions*

End-to-end latency in interactive systems is detrimental to performance and usability, and comes from a combination of hardware and software delays. While these delays are steadily addressed by hardware and software improvements, it is at a decelerating pace. In parallel, short-term input prediction has recently shown promising results to compensate for latency, in both research and industry.

In the context of the collaborative TurboTouch project, we proposed a method based on a frequency-domain approximation of a non-causal ideal predictor with a finite impulse response filter. Given a sufficiently rich dataset, the parameters of the filter can be either optimized off-line or tuned on-line with the proposed adaptive algorithm. The performance of the proposed solution is evaluated in an experimental study consisting of drawings on a touchscreen [13].

On the related topic of transfer functions, we proposed a switched dynamic model to model indirect pointing tasks with a computer mouse. The model contains a ballistic movement phase governed by a nonlinear model in Lurie form and a corrective movement phase described by a linear visual-feedback system. The stability of the model was evaluated and the derived model was then validated with experimental data acquired in a pointing task with a mouse. Numerical comparison to pointing models available in the literature is also provided [12].

7.2.2. 3D interaction

Raycasting is the most common target pointing technique in virtual reality environments. However, performance on small and distant targets is impacted by the accuracy of the pointing device and the user's motor skills. Current pointing facilitation techniques are currently only applied in the context of the virtual hand, i.e. for targets within reach. We proposed enhancements to Raycasting: filtering the ray, and adding a controllable cursor on the ray to select the nearest target (Figure 2). We ran a series of studies for the design of the visual feedforward, filtering technique, as well as a comparative study between different 3D pointing techniques. Our results show that highlighting the nearest target is one of the most efficient visual feedforward technique. We also show that filtering the ray reduces error rate in a drastic way. Finally we show the benefits of RayCursor compared to Raycasting and another technique from the literature [19], [14].
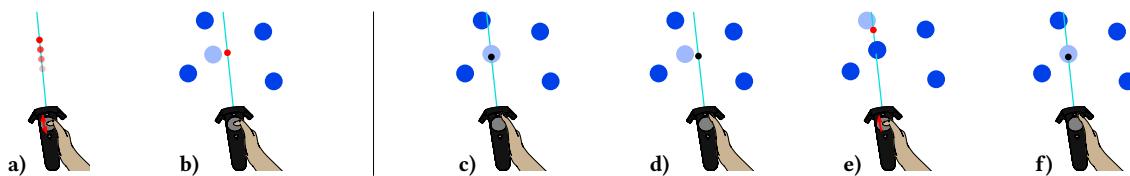

Figure 2. Illustration of manual RayCursor: a) the user controls a cursor along the ray using relative displacements of their thumb on the controller's touchpad; b) the target closest to the cursor is highlighted. Illustration of semi-auto RayCursor: c) by default, it works like Raycasting. The cursor (in black) is positioned at the intersection with a target; d) the target remains selected if the cursor moves out of the target, until it is closer to another target; e) the user can manually move the cursor using the controller's touchpad, to select another target (the cursor turns red to indicate manual mode); f) if the user does not touch the touchpad for 1s, the cursor returns to its behaviour described in c).

7.3. Meso-dynamics

Participants: Axel Antoine, Marc Baloup, Géry Casiez, Stéphane Huot, Edward Lank, Sylvain Malacria, Mathieu Nancel, Thomas Pietrzak [contact person], Thibault Raffaillac, Marcelo Wanderley.

7.3.1. Production of illustrative supports

Trace figures are contour drawings of people and objects that capture the essence of scenes without the visual noise of photos or other visual representations. Their focus and clarity make them ideal representations to illustrate designs or interaction techniques. In practice, creating those figures is a tedious task requiring advanced skills, even when creating the figures by tracing outlines based on photos. To mediate the process of creating trace figures, we introduce the open-source tool Esquisse (Figure 3). Informed by our taxonomy of 124 trace figures, Esquisse provides an innovative 3D model staging workflow, with specific interaction techniques that facilitate 3D staging through kinematic manipulation, anchor points and posture tracking. Our rendering algorithm (including stroboscopic rendering effects) creates vector-based trace figures of 3D scenes. We validated Esquisse with an experiment where participants created trace figures illustrating interaction techniques, and results show that participants quickly managed to use and appropriate the tool [18].

7.3.2. Impact of confirmation modes on expert interaction techniques adoption

Expert interaction techniques such as gestures or keyboard shortcuts are more efficient than traditional WIMP techniques because it is often faster to recall a command than to navigate to it. However, many users seem to be reluctant to switch to expert interaction. We hypothesized the cause might be the aversion to making errors. To test this, we designed two intermediate modes for the FastTap interaction technique, allowing quick confirmation of what the user has retrieved from memory, and quick adjustment if she made an error. We investigated the impact of these modes and of various error costs in a controlled study, and found that
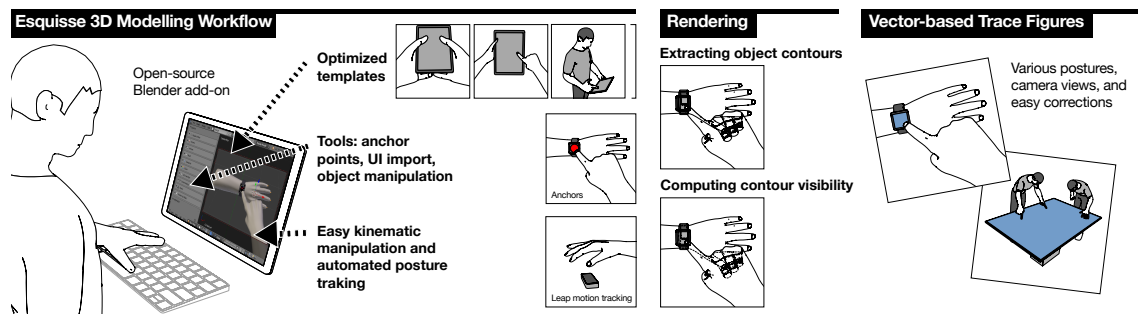
Figure 3. Workflow of Esquisse: (left) facilitating staging of 3D scenes with templates, anchor points, direct UI import, kinematic manipulation and automated posture tracking, (center) Esquisse's algorithm rendering the tracing images, and (right) final vector-based trace figures.

participants adopted the intermediate modes, that these modes reduced error rate when the cost of errors was high, and that they did not substantially change selection times. However, while it validates the design of our intermediate modes, we found no evidence of greater switch to memory-based interaction, suggesting that reducing error rate is not sufficient to motivate the adoption of expert use of techniques [25].

7.3.3. *Effect of the context on mobile interaction*

7.3.3.1. *Pointing techniques for eyewear using a simulated pedestrian environment*

Eyewear displays allow users to interact with virtual content displayed over real-world vision, in active situations like standing and walking. Pointing techniques for eyewear displays have been proposed, but their social acceptability, efficiency, and situation awareness remain to be assessed. Using a novel street-walking simulator, we conducted an empirical study of target acquisition while standing and walking under different levels of street crowdedness. Results showed that indirect touch was the most efficient and socially acceptable technique, and that in-air pointing was inefficient when walking. Interestingly, the eyewear displays did not improve situation awareness compared to the control condition [23].

7.3.3.2. *Studying smartphone motion gestures in private or public contexts*

We also investigated the effect of social exposure on smartphone motion gestures. We conducted a study where participants performed sets of motion gestures on a smartphone in both private and public locations. Using data from the smartphone's accelerometer, we found that the location had a significant effect on both the duration and intensity of the participants' gestures. We concluded that it may not be sufficient for gesture input systems to be designed and calibrated purely in private lab settings. Instead, motion gesture input systems for smartphones may need to be aware of the changing context of the device and to account for this in algorithms that interpret gestural input [26].

7.4. Macro-dynamics

Participants: Stéphane Huot, Sylvain Malacria [contact person], Nicole Pong.

7.4.1. *Awareness, usage and discovery of hidden controls*

Revealing a hidden widget with a dedicated sliding gesture is a common interaction design in today's handheld devices. Such "Swhidgets" (for swipe-revealed hidden widgets) provide a fast (and sometime unique) access to some commands. Interestingly, swhidgets do not follow conventional design guidelines in that they have no explicit signifiers, and users have to discover their existence before being able to use them. We conducted the first two studies specifically targeted to this type of interface design, investigating iOS users' experience with

swhidgets. The first study conducted in a laboratory setting investigated which Swhidgets are spontaneously used by participants when prompted to perform certain operations on an iOS device. The second study conducted via an online survey platform, investigated which Swhidgets users reported to know and use. Combined, our studies provide the following main insights on awareness, usage and discovery of Swhidgets by middle-aged and technology-friendly users. Our results suggest that Swhidgets are moderately but unevenly known by participants, yet the awareness and the discovery issues of this design is worthy of further discussion [21].

7.5. Interaction Machine

Two of our contributions this year relate specifically to our Interaction Machine project.

7.5.1. *Definition of Brain-Computer Interfaces*

Regardless of the term used to designate them, Brain-Computer Interfaces are "Interfaces" between a user and a computer in the broad sense of the term. We provided a perspective to discuss how BCIs have been defined in the literature from the day the term was introduced by Jacques Vidal. From a Human-Computer Interaction perspective, we propose a new definition of Brain-Computer Interfaces as "any artificial system that transforms brain activity into input of a computer process" [24]. As they are interfaces, their definition should not include the finality and objective of the system they are used to interact with. To illustrate this, we compared BCIs with other widely used Human-Computer Interfaces, and draw analogies in their conception and purpose. This definition would help better encompassing for such interfaces in systems design, and more generally inform on how to better manage diverse forms of input in an Interaction Machine.

7.5.2. *Software architecture for interactive systems*

On the software engineering side, we have proposed a new Graphical User Interface (GUI) and Interaction framework based on the Entity-Component-System model (ECS) [22]. In this model, interactive elements (Entities) are characterized only by their data (Components). Behaviors are managed by continuously running processes (Systems) which select entities by the Components they possess. This model facilitates the handling of behaviors and promotes their reuse. It provides developers with a simple yet powerful composition pattern to build new interactive elements with Components. It materializes interaction devices as Entities and interaction techniques as a sequence of Systems operating on them. We have implemented these principles in the Polyphony toolkit in order to experiment the ECS model in the context of GUIs programming. It has proven to be useful and efficient for modeling standard interaction techniques, and we are now exploring its benefits for prototyping and implementing more advanced methods in a modular way. It also raises some interesting challenges about performance and scalability that we will explore further.

7.5.3. *From the dynamics of interaction to an Interaction Machine*

Several of our new results this year also informed our global objective of building an Interaction Machine. At the micro-dynamics level, as last year, our work on prediction algorithms and transfer functions highlighted the need for accessing low-level input data and to have flexible input management to be able to reliably predict current finger position and compensate for latency. Our work on new selection methods in 3D also highlighted the importance of easing the combination of input events from multiple sources and of data filtering to achieve better interaction. As it also leverages the real time aspect of the perception-action coupling for efficient interaction, it also confirms the need for efficient and low-latency input management stacks. These results give us the first leads to redefine input management and input events propagation in order to better account for human factors in interactive systems, and to extend the possibilities for designing more efficient and expressive interaction methods.

At the meso-dynamics level, our studies on the adoption of expert interaction techniques and of the impact of the context in performing interaction gestures highlighted the need for both adaptable and adaptive systems (e.g. context-based calibration of gesture recognition algorithms), which require more modular and flexible system architectures in order to enable real-time parametrization or even switching interaction techniques. These results also resonate with those at the micro-dynamics level, since they suggest strong links between

users' behaviors and strategies (meso) and their low-level perception mechanisms (micro) that should be better taken into account in the design of interactive systems.

These conclusions and observations will be the basis for our investigations on the topic next year. We will in particular focus on the redefinition of the input stack and on applying the ECS model to the whole architecture of an interactive system.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

A research agreement between Synaptics Incorporated (San Jose, California) and Inria/Loki has been signed in September 2019, for a duration of nine months. The goal is to conduct joint studies on the impact of touchpads' characteristics (size, resolution) on the quality of interaction and users' performance.

8.2. Bilateral Grants with Industry

Géry Casiez and Mathieu Nancel have been awarded a Google Faculty Research Award for their project "Real-time Latency Measure and Compensation".

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. GeneaLire (CPER MAuVE, 2018-2020)
Participants: Stéphane Huot, Thomas Pietrzak [contact person].

Interactive tools for the interpretation of manuscripts

The goal of this project is to design, implement and evaluate interactive tools for helping transcription of scanned handwritten documents. Current solutions focus on automatic recognition, with recent advances thanks to deep learning methods. However these solutions still require a significant learning base that has to be made by hand. Not only this means that part of the work cannot be done automatically, but it also means that this technique is not a solution for small collections of documents. The tools we propose to create will ingeniously take advantage of interactive and automatic techniques. The interactive tools include a text selection technique [32], as well as advanced annotation techniques that will support collaborative work. This tool will be invaluable for bootstrapping the transcription of large collections, as well as helping transcribing small collections. We will use user-centered design, in order to make sure the tool fits historians and genealogists activities and workflow.

Partners: Inria Saclay's AVIZ team, École Polytechnique de l'Université de Tours, Laboratoire de Démographie et d'Histoire Sociale at l'École des hautes études en sciences sociales, and Geneanet.

9.2. National Initiatives

9.2.1. ANR

9.2.1.1. TurboTouch (PRC, 2014-2019)
Participants: Géry Casiez [contact person], Sylvain Malacria, Mathieu Nancel, Thomas Pietrzak.

High-performance touch interactions

Touch-based interactions with computing systems are greatly affected by two interrelated factors: the transfer functions applied on finger movements, and latency. This project aims at transforming the design of touch transfer functions from black art to science to support high-performance interactions. We are working on the precise characterization of the functions used and the latency observed in current touch systems. We are developing a testbed environment to support multidisciplinary research on touch transfer functions and will use this testbed to design latency reduction and compensation techniques, and new transfer functions.

Partners: Inria Lille's VALSE team (formerly NON-A) and the "Perceptual-motor behavior group" from the Institute of Movement Sciences.

Web site: http://mjolnir.lille.inria.fr/turbotouch/

Related publications in 2019: [13], [12]

9.2.1.2. Causality (JCJC, 2019-2023)

Participants: Géry Casiez, Stéphane Huot, Sylvain Malacria, Mathieu Nancel [contact person], Philippe Schmid.

Integrating Temporality and Causality to the Design of Interactive Systems

The project addresses a fundamental limitation in the way interfaces and interactions are designed and even thought about today, an issue we call *procedural information loss*: once a task has been completed by a computer, significant information that was used or produced while processing it is rendered inaccessible regardless of the multiple other purposes it could serve. It hampers the identification and solving of identifiable usability issues, as well as the development of new and beneficial interaction paradigms. We will explore, develop, and promote finer granularity and better-described connections between the causes of those changes, their context, their consequences, and their timing. We will apply it to facilitate the real-time detection, disambiguation, and solving of frequent timing issues related to human reaction time and system latency; to provide broader access to all levels of input data, therefore reducing the need to "hack" existing frameworks to implement novel interactive systems; and to greatly increase the scope and expressiveness of command histories, allowing better error recovery but also extended editing capabilities such as reuse and sharing of previous actions.

Web site: http://loki.lille.inria.fr/causality/

9.2.1.3. Discovery (JCJC, 2020-2024)

Participant: Sylvain Malacria [contact person].

Promoting and improving discoverability in interactive systems

This project addresses a fundamental limitation in the way interactive systems are usually designed, as in practice they do not tend to foster the discovery of their input methods (operations that can be used to communicate with the system) and corresponding features (commands and functionalities that the system supports). Its objective is to provide generic methods and tools to help the design of discoverable interactive systems: we will define validation procedures that can be used to evaluate the discoverability of user interfaces, design and implement novel UIs that foster input method and feature discovery, and create a design framework of discoverable user interfaces. This project investigates, but is not limited to, the context of touch-based interaction and will also explore two critical timings when the user might trigger a reflective practice on the available inputs and features: while the user is carrying her task (discovery in-action); and after having carried her task by having informed reflection on her past actions (discovery on-action). This dual investigation will reveal more generic and context-independent properties that will be summarized in a comprehensive framework of discoverable interfaces. Our ambition is to trigger a significant change in the way all interactive systems and interaction techniques, existing and new, are thought, designed, and implemented with both performance and discoverability in mind.

Web site: http://ns.inria.fr/discovery/

Related publications in 2019: [21].

9.2.2. Inria Project Labs

9.2.2.1. BCI-LIFT (2015-2019)
Participant: Géry Casiez [contact person].

Brain Computer Interfaces: Learning, Interaction, Feedback, Training

The goal of this large-scale initiative is to design a new generation of non-invasive Brain-Computer Interfaces (BCI) that are easier to appropriate, more efficient, and suited for a larger number of people.

Partners: Inria's ATHENA, NEUROSYS, POTIOC, HYBRID & DEMAR teams, *Centre de Recherche en Neurosciences de Lyon* (INSERM) and INSA Rouen.

Web site: https://bci-lift.inria.fr/

Related publication in 2019: [24]

9.2.2.2. AVATAR (2018-2022)
Participants: Géry Casiez, Stéphane Huot, Thomas Pietrzak [contact person].

The next generation of our virtual selves in digital worlds

This project aims at delivering the next generation of virtual selves, or *avatars*, in digital worlds. In particular, we want to push further the limits of perception and interaction through our avatars to obtain avatars that are better embodied and more interactive. Loki's contribution in this project consists in designing novel 3D interaction paradigms for avatar-based interaction and to design new multi-sensory feedbacks to better feel our interactions through our avatars.

Partners: Inria's GRAPHDECO, HYBRID, MIMETIC, MORPHEO & POTIOC teams, Mel Slater (Event Lab, University Barcelona, Spain), Technicolor and Faurecia.

Web site: https://avatar.inria.fr/

Related publication in 2019: [19], [14]

9.2.3. Others

9.2.3.1. ParkEvolution (Carnot Inria - Carnot STAR, 2015-2019)
Participant: Géry Casiez [contact person].

Longitudinal analysis of fine motor control for patients with Parkinson disease

This project studies the fine motor control of patients with Parkinson disease in an ecological environment, at home, without the presence of experimenters. Through longitudinal studies, we collect raw information from pointing devices to create a large database of pointing behavior data. From the analysis of this big dataset, the project aims at inferring the individual's disease progression and influence of treatments.

Partners: the "Perceptual-motor behavior group" from the Institute of Movement Sciences and Hôpital de la Timone.

Web site: http://parkevolution.org/

9.2.3.2. IRDICS (Projets Exploratoires Premier Soutien CNRS, 2018-2019)
Participants: Géry Casiez, Stéphane Huot, Sylvain Malacria, Thomas Pietrzak [contact person].

Interface de recueil de données imparfaites pour le crowd-sourcing

Many crowdsourcing studies involve asking hundreds of participants to answer questionnaires. There is typically a trade-off between precision and certitude of participants. Usually, investigators prefer participants to be certain, at the cost of precision. The idea is that the lack of precision can be compensated by the high number of answers. In this project we are interested in studying this trade-off. We performed a first study, in which we asked participants to rate their confidence in their answer. In the next studies, we will allow participants to give several answers, but make sure the right answer is among them. In the last study, participants will be able to rank their answers based on confidence.

Partners: IRISA's DRUID team.

Related publication in 2019: [31]

9.3. International Initiatives

9.3.1. Inria International Partners

9.3.1.1. Informal International Partners

Andy Cockburn, University of Canterbury, Christchurch, NZ [25], [23]

Carl Gutwin, University of Saskatchewan, Saskatoon, CA [25]

Nicolai Marquardt, University College London, London, UK [18]

Antti Oulasvirta, Aalto University, Helsinki, FI

Daniel Vogel, University of Waterloo, Waterloo, CA

Audrey Girouard, Carleton University, Ottawa, CA

9.3.2. Participation in Other International Programs

9.3.2.1. Inria International Chairs

Expert interaction with devices for musical expression

Marcelo M. Wanderley – *Professor at Schulich School of Music/IDMIL, McGill University (Canada)*

Period: 2017 - 2021

The main topic of this project is the expert interaction with devices for musical expression and consists of two main directions: *the design of digital musical instruments* (DMIs) and *the evaluation of interactions with such instruments*. It will benefit from the unique, complementary expertise available at the Loki Team, including the design and evaluation of interactive systems, the definition and implementation of software tools to track modifications of, visualize and haptically display data, as well as the study of expertise development within human-computer interaction contexts. The project's main goal is to bring together advanced research on devices for musical expression (IDMIL – McGill) and cutting-edge research in Human-computer interaction (Loki Team).

Rich, Reliable Interaction in Ubiquitous Environments

Edward Lank – *Professor at Cheriton School of Computer Science, University of Waterloo (Canada)*

Period: 2019 - 2023

The objectives of the research program are:

1. Designing Rich Interactions for Ubiquitous and Augmented Reality Environments
2. Designing Mechanisms and Metaphors for Novices, Experts, and the Novice to Expert Transition
3. Integrating Intelligence with Human Action in Richly Augmented Environments.

9.3.2.2. Université de Lille - International Associate Laboratory

Reappearing Interfaces in Ubiquitous Environments (Réapp)

with Edward Lank, Daniel Vogel & Keiko Katsuragawa at University of Waterloo (Canada) - Cheriton School of Computer Science

Duration: 2019 - 2023

The LIA Réapp is an International Associated Laboratory between Loki and Cheriton School of Computer Science from the University of Waterloo in Canada. It is funded by the University of Lille to ease shared student supervision and regular inter-group contacts. The University of Lille will also provide a grant for a co-tutelle PhD thesis between the two universities.

We are at the dawn of the next computing paradigm where everything will be able to sense human input and augment its appearance with digital information without using screens, smartphones, or special glasses—making user interfaces simply disappear. This introduces many problems for users, including the discoverability of commands and use of diverse interaction techniques, the acquisition of expertise, and the balancing of trade-offs between inferential (AI) and explicit (user-driven) interactions in aware environments. We argue that interfaces must reappear in an appropriate way to make ubiquitous environments useful and usable. This project tackles these problems, addressing (1) the study of human factors related to ubiquitous and augmented reality environments, and the development of new interaction techniques helping to make interfaces reappear; (2) the improvement of transition between novice and expert use and optimization of skill transfer; and, last, (3) the question of delegation in smart interfaces, and how to adapt the trade-off between implicit and explicit interaction.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

Edward Lank, Professor at the University of Waterloo, who has been awarded an Inria International Chair in our team in 2019, spent 4 months in our group this year (September to December).

Marcelo M. Wanderley, Professor at McGill University, who has been awarded an Inria International Chair in our team in 2017, spent 2 months in our group this year (July to August).

9.4.1.1. Internships

Carola Trahms, PhD student, Christian-Albrecht University of Kiel, Sep. 2019.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organization

10.1.1.1. General Chair, Scientific Chair

- HAID 2019: Thomas Pietrzak, Marcelo Wanderley

10.1.2. Scientific Events: Selection

10.1.2.1. Chair of Conference Program Committees

- IHM (AFIHM): Thomas Pietrzak

10.1.2.2. Member of the Conference Program Committees

- CHI (ACM): Géry Casiez, Stéphane Huot, Thomas Pietrzak
- IHM (AFIHM): Mathieu Nancel, Thibault Raffaillac (Work in Progress)
- WebMedia (SBC): Raiza Hanada
- ISS (ACM): Sylvain Malacria

10.1.2.3. Reviewer

- CHI (ACM): Géry Casiez, Stéphane Huot, Sylvain Malacria, Mathieu Nancel, Thomas Pietrzak
- UIST (ACM): Géry Casiez, Sylvain Malacria, Mathieu Nancel, Thomas Pietrzak
- IDC (ACM): Géry Casiez
- DIS (ACM): Stéphane Huot, Mathieu Nancel
- GI: Géry Casiez, Mathieu Nancel
- ISS (ACM): Mathieu Nancel, Thomas Pietrzak
- SUI (ACM): Mathieu Nancel

10.1.3. Journal

10.1.3.1. Reviewer - Reviewing Activities

- Transactions on Computer-Human Interaction (ACM): Géry Casiez, Thomas Pietrzak, Mathieu Nancel
- Intl. Journal of Human-Computer Studies (Elsevier): Sylvain Malacria
- User Modeling and User-Adapted Interaction (Springer): Sylvain Malacria

10.1.4. Invited Talks

- *Who [was\is\will be] in Control?: Some Control-Related Challenges in Interacting with Complex Systems*, 2nd JST-ANR Joint Symposium: Symbiotic Interaction, Tokyo, Japan: Stéphane Huot

10.1.5. Leadership within the Scientific Community

Association Francophone d'Interaction Homme-Machine (AFIHM):

- Géry Casiez: member of the scientific council since March 2019
- Stéphane Huot: member of the scientific council until March 2019

10.1.6. Scientific Expertise

- Agence Nationale de la Recherche: Stéphane Huot (vice-chair for the CES33 "Interaction and Robotics" committee)
- CN35 AFNOR normalization committee about normalizing the French keyboard: Mathieu Nancel (publication of the NF Z71-300 standard)

10.1.7. Research Administration

10.1.7.1. For Inria

- International relations working group (COST-GTRI): Stéphane Huot (member)

10.1.7.2. For Inria Lille – Nord Europe

- "Bureau du comité des équipes projets" (BCEP): Stéphane Huot (member)
- "Commission des Emplois de recherche du centre Inria Lille – Nord Europe" (CER): Sylvain Malacria (member)
- "Comité opérationnel d'évaluation des risques légaux et éthiques" (COERLE, the Inria Ethics board): Stéphane Huot (local correspondent)
- "Commission de développement technologique" (CDT): Mathieu Nancel (member)

10.1.7.3. For the CRIStAL lab of Université de Lille & CNRS

- Direction board: Géry Casiez
- Computer Science PhD recruiting committee: Géry Casiez (member)

10.1.7.4. For the Université de Lille

- Coordinator for internships at IUT A: Géry Casiez
- Computer Science Department council: Thomas Pietrzak

10.1.8. Hiring committees

- Université de Valenciennes hiring committee for a Computer Science Professor position: Géry Casiez (member)
- ENAC hiring committee for a Computer Science faculty position: Stéphane Huot (member)

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

DUT Informatique: Géry Casiez (38h), Stéphane Huot (28h), Axel Antoine (28h), Thibault Raffaillac (56h) *IHM*, 1st year, IUT A de Lille - Université de Lille

DUT Informatique: Axel Antoine (32h), CDIN-CALC, 1st year, IUT A de Lille - Université de Lille

DUT Informatique: Marc Baloup, Algorithme et Programmation, 21.5h, 1st year, IUT A de Lille - Université de Lille

DUT Informatique: Marc Baloup, CDIN Web, 11h, 1st year, IUT A de Lille - Université de Lille

DUT Informatique: Thibault Raffaillac, Codage et Systèmes d'exploitation, 64h, 1st year, IUT A de Lille - Université de Lille

DUT Informatique: Thibault Raffaillac, Algorithmique avancée, 64h, 1st year, IUT A de Lille - Université de Lille

Licence Informatique: Thomas Pietrzak, *Logique*, 36h, L3, Université de Lille

Licence Informatique: Thomas Pietrzak, *Image et Interaction 2D*, 10.5h, L3, Université de Lille

Cursus ingénieur: Sylvain Malacria (10h), *3DETech*, IMT Lille-Douai

Master Informatique: Thomas Pietrzak (18h), *NIHM*, M2, Université de Lille

Master Informatique: Sylvain Malacria (12h), *NIHM*, M2, Université de Lille

Master Informatique: Thomas Pietrzak (34.5h), Sylvain Malacria (34.5), *IHM*, M1, Université de Lille

Master Informatique: Mathieu Nancel, *Evaluation*, 8h, M2, Université de Lille

10.2.2. Supervision

PhD: Thibault Raffaillac, *Languages and System Infrastructure for Interaction*, defended in Dec. 2019, advised by Stéphane Huot

PhD: Hakim Si Mohammed, *Improving Interaction Based on a Brain-Computer Interface*, defended in Dec. 2019, advised by Anatole Lecuyer, Ferran Argelaguet, Géry Casiez & Nicolas Roussel (in Rennes)

PhD: Jeronimo Barbosa, *Design and Evaluation of Digital Musical Instruments*, McGill University, defended in May 2019, advised by Marcelo Wanderley & Stéphane Huot (in Montréal)

PhD in progress: Grégoire Richard, *Touching avatars : le rôle du retour haptique dans les interactions avec les avatars en réalité virtuelle*, started Oct. 2019, advised by Géry Casiez & Thomas Pietrzak

PhD in progress: Philippe Schmid, *Command History as a Full-fledged Interactive Object*, started Oct. 2019, advised by Mathieu Nancel & Stéphane Huot

PhD: Damien Masson, *Supporting Interactivity with Static Content*, University of Waterloo, started in January 2019, advised by Edward Lank, Géry Casiez & Sylvain Malacria (in Waterloo)

PhD in progress: Marc Baloup, *Interaction with avatars in immersive virtual environments*, started Oct. 2018, advised by Géry Casiez & Thomas Pietrzak

PhD in progress: Axel Antoine, *Helping Users with Interactive Strategies*, started Oct. 2017, advised by Géry Casiez & Sylvain Malacria

PhD in progress: Nicole Ke Chen Pong, *Understanding and Improving Users Interactive Vocabulary*, started Oct. 2016, advised by Nicolas Roussel, Sylvain Malacria & Stéphane Huot

10.2.3. Juries

Hugo Romat (PhD, Université Paris-Saclay): Stéphane Huot, president

Emmanouil Giannisakis (PhD, Université Paris-Saclay): Géry Casiez, reviewer

Marie-Éléonore Kessaci (HDR, Université de Lille): Géry Casiez, president

10.2.4. Mid-term evaluation committees

Antonin Durey (PhD, Université de Lille): Géry Casiez

Théo Voillemin (PhD, Université de Lille): Géry Casiez

Vikas Mishra (PhD, Université de Lille): Géry Casiez

10.3. Popularization

10.3.1. Internal or external Inria responsibilities

AIRLab selection committee for the funding of art and science projects, Stéphane Huot (representative for Inria Lille – Nord Europe)

10.3.2. Articles and contents

The Mother Of All Demos, l'autre révolution de 1968, interview for Carré, Petit, Utile : Le programme radio des gens du numérique on Radio <FMR>, Stéphane Huot

web series *Dopamine* on Arte.tv, scientific expertise, Stéphane Huot

10.3.3. Interventions

Intervention during the official launch event of the new NF Z71-300 French keyboard standard at the Assemblée Nationale: Mathieu Nancel

11. Bibliography

Major publications by the team in recent years

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[2] G. CASIEZ, S. CONVERSY, M. FALCE, S. HUOT, N. ROUSSEL. *Looking through the eye of the mouse: a simple method for measuring end-to-end latency using an optical mouse*, in "Proceedings of UIST'15", ACM, November 2015, pp. 629-636, http://dx.doi.org/10.1145/2807442.2807454

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