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CNRS

Université Paris-Sud (Paris 11)

Activity Report 2017

Project-Team ILDA

Interacting with Large Data

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

RESEARCH CENTER
Saclay - Île-de-France

THEME
Interaction and visualization

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Project-Team ILDA

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A3.2.4. - Semantic Web
A3.2.5. - Ontologies
A5.1. - Human-Computer Interaction
A5.2. - Data visualization
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Other Research Topics and Application Domains:

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1. Personnel

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2. Overall Objectives

2.1. Overall Objectives

In an increasing number of domains, computer users are faced with large datasets, that are often interlinked and organized according to elaborate structures thanks to new data models such as those that are arising with the development of, e.g., the Web of Data. Rather than seeing the inherent complexity of those data models as a hindrance, we aim at leveraging it to design new interactive systems that can better assist users in their data understanding and processing tasks.

These "Data-centric Interactive Systems" aim at providing users with the right information at the right time, presenting it in the most meaningful manner, and letting users efficiently manipulate, edit and share these data with others. This entails minimizing the effort required to retrieve and relate data from relevant sources; displaying data using visual presentation techniques that match the data's characteristics and the users' tasks; and providing users with means of interacting with the data that effectively support their train of thought.

Our approach is based on the idea of bringing the fields of Web data management [28] and Human-computer interaction [53], [75] closer together, based on the strong belief that they have the potential to cross-fertilize one another. User interface design is essential to the management and understanding of large, interlinked datasets. Interlinked datasets enriched with even a small amount of semantics have the potential to help create interfaces that let users analyze and manipulate data in a more efficient manner by providing them with, e.g, more relevant query results and giving them efficient means to navigate and relate those results. Our ultimate, long-term goal is to design interactive systems that make it as straightforward to manipulate large webs of data as spreadsheets do for tabular data.

3. Research Program

3.1. Introduction

Our ability to acquire or generate, store, process, interlink and query data has increased spectacularly over the last few years. The corresponding advances are commonly grouped under the umbrella of so called *Big Data*. Even if the latter has become a buzzword, these advances are real, and they are having a profound impact in domains as varied as scientific research, commerce, social media, industrial processes or e-government. Yet, looking ahead, emerging technologies related to what we now call the *Web of Data* (a.k.a the Semantic Web) have the potential to create an even larger revolution in data-driven activities, by making information accessible to machines as semistructured data [27] that eventually becomes actionable knowledge. Indeed, novel Web data models considerably ease the interlinking of semi-structured data originating from multiple independent sources. They make it possible to associate machine-processable semantics with the data. This in turn means that heterogeneous systems can exchange data, infer new data using reasoning engines, and that software agents can cross data sources, resolving ambiguities and conflicts between them [73]. Datasets are becoming very rich and very large. They are gradually being made even larger and more heterogeneous, but also much more useful, by interlinking them, as exemplified by the Linked Data initiative [48].

These advances raise research questions and technological challenges that span numerous fields of computer science research: databases, communication networks, security and trust, data mining, as well as human-computer interaction. Our research is based on the conviction that interactive systems play a central role in many data-driven activity domains. Indeed, no matter how elaborate the data acquisition, processing and storage pipelines are, data eventually get processed or consumed one way or another by users. The latter are faced with large, increasingly interlinked heterogeneous datasets (see, e.g., Figure 1) that are organized according to complex structures, resulting in overwhelming amounts of both raw data and structured information. Users thus require effective tools to make sense of their data and manipulate them.

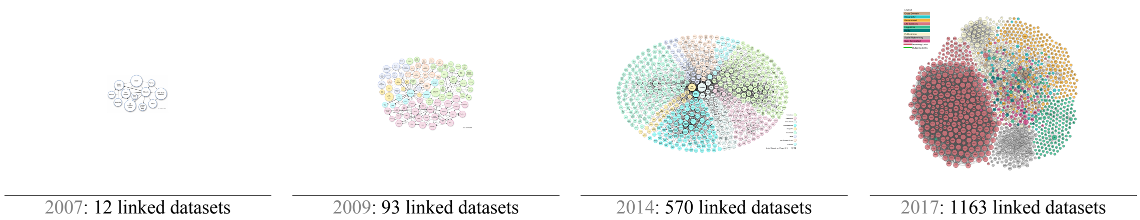


Figure 1. Linking Open Data cloud diagram from 2007 to 2017 – http://lod-cloud.net

We approach this problem from the perspective of the Human-Computer Interaction (HCI) field of research, whose goal is to study how humans interact with computers and inspire novel hardware and software designs aimed at optimizing properties such as efficiency, ease of use and learnability, in single-user or cooperative work contexts. More formally, HCI is about designing systems that lower the barrier between users' cognitive model of what they want to accomplish, and computers' understanding of this model. HCI is about the design, implementation and evaluation of computing systems that humans interact with [53], [75]. It is a highly multidisciplinary field, with experts from computer science, cognitive psychology, design, engineering, ethnography, human factors and sociology.

In this broad context, ILDA aims at designing interactive systems that display [37], [60], [82] the data and let users interact with them, aiming to help users better *navigate* and *comprehend* large webs of data represented visually, as well as *relate* and *manipulate* them.

Our research agenda consists of the three complementary axes detailed in the following subsections. Designing systems that consider interaction in close conjunction with data semantics is pivotal to all three axes. Those semantics will help drive navigation in, and manipulation of, the data, so as to optimize the communication bandwidth between users and data.

3.2. Semantics-driven Data Manipulation

Participants: Emmanuel Pietriga, Caroline Appert, Marie Destandau, Hugo Romat, Hande Gözükan, Dylan Lebout.

The Web of Data has been maturing for the last fifteen years and is starting to gain adoption across numerous application domains (Figure 1). Now that most foundational building blocks are in place, from knowledge representation, inference mechanisms and query languages [49], all the way up to the expression of data presentation knowledge [68] and to mechanisms like look-up services [81] or spreading activation [44], we need to pay significant attention to how human beings are going to interact with this new Web, if it is to *"reach its full potential"* [45].

Most efforts in terms of user interface design and development for the Web of data have essentially focused on tools for software developers or subject-matter experts who create ontologies and populate them [55], [43]. Tools more oriented towards end-users are starting to appear [34], [36], [50], [51], [54], [63], including the so-called *linked data browsers* [48]. However, those browsers are in most cases based on quite conventional point-and-click hypertext interfaces that present data to users in a very page-centric, web-of-documents manner that is ill-suited to navigating in, and manipulating, webs of data.

To be successful, interaction paradigms that let users navigate and manipulate data on the Web have to be tailored to the radically different way of browsing information enabled by it, where users directly interact with the data rather than with monolithic documents. The general research question addressed in this part of our research program is how to design novel interaction techniques that help users manipulate their data more efficiently. By data manipulation, we mean all low-level tasks related to manually creating new content, modifying and cleaning existing content, merging data from different sources, establishing connections between datasets, categorizing data, and eventually sharing the end results with other users; tasks that are currently considered quite tedious because of the sheer complexity of the concepts, data models and syntax, and the interplay between all of them.

Our approach is based on the conviction that there is a strong potential for cross-fertilization, as mentioned earlier: on the one hand, user interface design is essential to the management and understanding of webs of data; on the other hand, interlinked datasets enriched with even a small amount of semantics can help create more powerful user interfaces, that provide users with the right information at the right time.

We envision systems that focus on the data themselves, exploiting the underlying *semantics and structure* in the background rather than exposing them – which is what current user interfaces for the Web of Data often do. We envision interactive systems in which the semantics and structure are not exposed directly to users, but serve as input to the system to generate interactive representations that convey information relevant to the task at hand and best afford the possible manipulation actions.

Relevant publications by team members this year: [21], [15].

3.3. Generalized Multi-scale Navigation

Participants: Caroline Appert, Anastasia Bezerianos, Olivier Chapuis, Emmanuel Pietriga, Marie Destandau, Anna Gogolou, Maria Jesus Lobo Gunther, Arnaud Prouzeau, Vit Rusnak.

The foundational question addressed here is what to display when, where and how, so as to provide effective support to users in their data understanding and manipulation tasks. ILDA targets contexts in which workers have to interact with complementary views on the same data, or with views on different-but-related datasets, possibly at different levels of abstraction. Being able to combine or switch between representations of the data at different levels of detail and merge data from multiple sources in a single representation is central to many scenarios. This is especially true in both of the application domains we consider: mission-critical systems (e.g., natural disaster crisis management) and the exploratory analysis of scientific data (e.g., correlate theories and heterogeneous observational data for an analysis of a given celestial body in Astrophysics).

A significant part of our research over the last ten years has focused on multi-scale interfaces. We designed and evaluated novel interaction techniques, but also worked actively on the development of open-source UI toolkits for multi-scale interfaces (http://zvtm.sf.net). These interfaces let users navigate large but relatively homogeneous datasets at different levels of detail, on both workstations [71], [30], [67], [66], [65], [31], [70], [29], [72] and wall-sized displays [62], [57], [69], [61], [33], [39], [38]. This part of the ILDA research program is about extending multi-scale navigation in two directions: 1. Enabling the representation of multiple, spatially-registered but widely varying, multi-scale data layers in Geographical Information Systems (GIS); 2. Generalizing the multi-scale navigation paradigm to interconnected, heterogeneous datasets as found on the Web of Data.

The first research problem is mainly investigated in collaboration with IGN in the context of ANR project MapMuxing (Section 9.2.1), which stands for *multi-dimensional map multiplexing*. Project MapMuxing aims at going beyond the traditional pan & zoom and overview+detail interface schemes, and at designing and evaluating novel cartographic visualizations that rely on high-quality generalization, *i.e.*, the simplification of geographic data to make it legible at a given map scale [78], [79], and symbol specification. Beyond project MapMuxing, we are also investigating multi-scale multiplexing techniques for geo-localized data in the specific context of ultra-high-resolution wall-sized displays, where the combination of a very high pixel density and large physical surface (Figure 2) enable us to explore designs that involve collaborative interaction and physical navigation in front of the workspace. This is work done in cooperation with team Massive Data at Inria Chile.

The second research problem is about the extension of multi-scale navigation to interconnected, heterogeneous datasets. Generalization has a rather straightforward definition in the specific domain of geographical information systems, where data items are geographical entities that naturally aggregate as scale increases. But it is unclear how generalization could work for representations of the more heterogeneous webs of data that we consider in the first axis of our research program. Those data form complex networks of resources with multiple and quite varied relationships between them, that cannot rely on a single, unified type of representation (a role played by maps in GIS applications).

Addressing the limits of current generalization processes is a longer-term, more exploratory endeavor. Here again, the machine-processable semantics and structure of the data give us an opportunity to rethink how users navigate interconnected heterogeneous datasets. Using these additional data, we investigate ways to generalize the multi-scale navigation paradigm to datasets whose layout and spatial relationships can be much richer and much more diverse than what can be encoded with static linear hierarchies as typically found today in interfaces for browsing maps or large imagery. Our goal is thus to design and develop highly dynamic and versatile multi-scale information spaces for heterogeneous data whose structure and semantics are not known in advance, but discovered incrementally.

Relevant publications by team members this year: [17].

3.4. Novel Forms of Input for Groups and Individuals

Participants: Caroline Appert, Anastasia Bezerianos, Olivier Chapuis, Emmanuel Pietriga, Rafael Morales Gonzalez, Arnaud Prouzeau, Eleonore Bartenlian, Reyhaneh Raissi, Bruno Fruchard.

Analyzing and manipulating large datasets can involve multiple users working together in a coordinated manner in multi-display environments: workstations, handheld devices, wall-sized displays [33]. Those users work towards a common goal, navigating and manipulating data displayed on various hardware surfaces in a coordinated manner. Group awareness [47], [26] is central in these situations, as users, who may or may not be co-located in the same room, can have an optimal individual behavior only if they have a clear picture of what their collaborators have done and are currently doing in the global context. We work on the design and implementation of interactive systems that improve group awareness in co-located situations [56], making individual users able to figure out what other users are doing without breaking the flow of their own actions.

In addition, users need a rich interaction vocabulary to handle large, structured datasets in a flexible and powerful way, regardless of the context of work. Input devices such as mice and trackpads provide a limited number of input actions, thus requiring users to switch between modes to perform different types of data manipulation and navigation actions. The action semantics of these input devices are also often too much dependent on the display output. For instance, a mouse movement and click can only be interpreted according to the graphical controller (widget) above which it is moved. We focus on designing powerful input techniques based upon technologies such as tactile surfaces (supported by UI toolkits developed in-house), 3D motion tracking systems, or custom-built controllers [59] *to complement (rather than replace) traditional input devices* such as keyboards, that remain the best method so far for text entry, and indirect input devices such as mice or trackpads for pixel-precise pointing actions.

The input vocabularies we investigate enable users to navigate and manipulate large and structured datasets in environments that involve multiple users and displays that vary in their size, position and orientation [33], [46], each having their own characteristics and affordances: wall displays [62], [84], workstations, tabletops [64], [42], tablets [7], [80], smartphones [83], [40], [76], [77], and combinations thereof [2], [10], [61], [33].

We aim at designing rich interaction vocabularies that go far beyond what current touch interfaces offer, which rarely exceeds five gestures such as simple slides and pinches. Designing larger gesture vocabularies requires identifying discriminating dimensions (e.g., the presence or absence of anchor points and the distinction between internal and external frames of reference [7]) in order to structure a space of gestures that interface designers can use as a dictionary for choosing a coherent set of controls. These dimensions should be few and simple, so as to provide users with gestures that are easy to memorize and execute. Beyond gesture complexity, the scalability of vocabularies also depends on our ability to design robust gesture recognizers that will allow users to fluidly chain simple gestures that make it possible to interlace navigation and manipulation actions.

We also study how to further extend input vocabularies by combining touch [7], [83], [64] and mid-air gestures [62] with physical objects [52], [74], [59] and classical input devices such as keyboards to enable users to input commands to the system or to involve other users in their workflow (request for help, delegation, communication of personal findings, etc.) [35], [58]. Gestures and objects encode a lot of information in their shape, dynamics and direction, that can be directly interpreted in relation with the user, independently from the display output. Physical objects can also greatly improve coordination among actors for, e.g., handling priorities or assigning specific roles.

Relevant publications by team members this year: [11], [23], [22], [20], [24], [15], [14], [18].

4. Application Domains

4.1. Mission-critical systems

Mission-critical contexts of use include emergency response & management, and critical infrastructure operations, such as public transportation systems, communications and power distribution networks, or the operations of large scientific instruments such as particle accelerators and astronomical observatories. Central to these contexts of work is the notion of situation awareness [26], i.e., how workers perceive and understand elements of the environment with respect to time and space, such as maps and geolocated data feeds from the field, and how they form mental models that help them predict future states of those elements. One of the main challenges is how to best assist subject-matter experts in constructing correct mental models and making informed decisions, often under time pressure. This can be achieved by providing them with, or helping them efficiently identify and correlate, relevant and timely information extracted from large amounts of raw data, taking into account the often cooperative nature of their work and the need for task coordination. With this application area, our goal is to investigate novel ways of interacting with computing systems that improve collaborative data analysis capabilities and decision support assistance in a mission-critical, often time-constrained, work context.

Relevant publications by team members this year: [24], [15], [18], [17], [25].

4.2. Exploratory analysis of scientific data

Many scientific disciplines are increasingly data-driven, including astronomy, molecular biology, particle physics, or neuroanatomy. While making the right decision under time pressure is often less of critical issue when analyzing scientific data, at least not on the same temporal scale as truly time-critical systems, scientists are still faced with large-to-huge amounts of data. No matter their origin (experiments, remote observations, large-scale simulations), these data are difficult to understand and analyze in depth because of their sheer size and complexity. Challenges include how to help scientists freely-yet-efficiently explore their data, keep a trace of the multiple data processing paths they considered to verify their hypotheses and make it easy to backtrack, and how to relate observations made on different parts of the data and insights gained at different moments during the exploration process. With this application area, our goal is to investigate how data-centric interactive systems can improve collaborative scientific data exploration, where users' goals are more open-ended, and where roles, collaboration and coordination patterns [47] differ from those observed in mission-critical contexts of work.

Relevant publications by team members last year: [8].

5. Highlights of the Year

5.1. Highlights of the Year

- Caroline Appert was papers co-chairs for the 2017 ACM CHI Conference on Human Factors in Computing Systems, the flagship conference in HCI, with more than 2,400 submissions in 2017.
- Caroline Appert joined the editorial board of ACM ToCHI (Transactions on Computer-Human Interaction), one of the two top journals in HCI.

6. New Software and Platforms

6.1. Smarties

FUNCTIONAL DESCRIPTION: The Smarties system provides an easy way to add mobile interactive support to collaborative applications for wall displays.

It consists of (i) a mobile interface that runs on mobile devices for input, (ii) a communication protocol between the mobiles and the wall application, and (iii) libraries that implement the protocol and handle synchronization, locking and input conflicts. The library presents the input as an event loop with callback functions and handles all communication between mobiles and wall application. Developpers can customize the mobile interface from the wall application without modifying the mobile interface code.

On each mobile we find a set of cursor controllers associated with keyboards, widgets and clipboards. These controllers (pucks) can be shared by multiple collaborating users. They can control simple cursors on the wall application, or specific content (objects or groups of them). The developper can decide the types of widgets associated to pucks from the wall application side.

- Contact: Olivier Chapuis
- URL: http://smarties.lri.fr/

6.2. ZVTM

Zoomable Visual Transformation Machine
KEYWORDS: Big data - Visualization - Data visualization - Information visualization - Graph visualization
FUNCTIONAL DESCRIPTION: ZVTM is a toolkit enabling the implementation of multi-scale interfaces for interactively navigating in large datasets displayed as 2D graphics.

ZVTM is used for browsing large databases in multiple domains: geographical information systems, control rooms of complex facilitites, astronomy, power distribution systems.

The toolkit also enables the development of applications running on ultra-high-resolution wall-sized displays.

- Participants: Arnaud Prouzeau, Can Liu, Caroline Appert, Hande Gozukan, Maria Jesus Lobo Gunther and Olivier Chapuis
- Contact: Emmanuel Pietriga
- URL: http://zvtm.sf.net

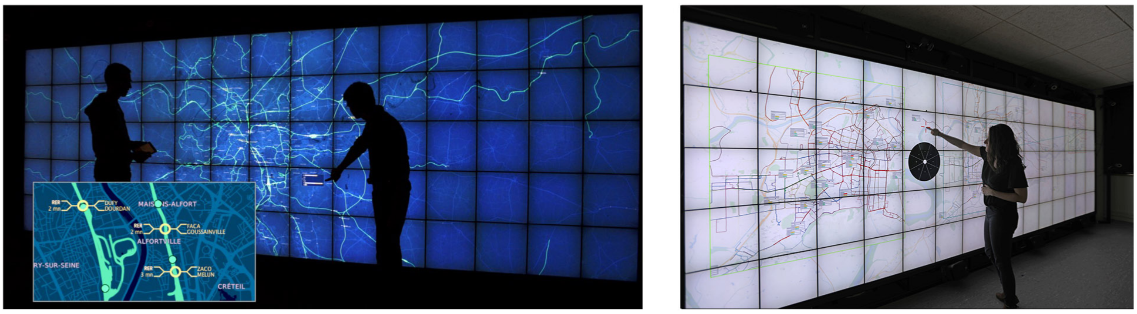


Figure 2. Geovisualization applications running on the WILDER platform. Real-time monitoring of railroad traffic in France (left), real-time monitoring of mobile sensors measuring air quality in Korean cities (right).

6.3. Platforms

6.3.1. Platform: WILDER

Ultra-high-resolution wall-sized displays [33] feature a very high pixel density over a large physical surface. Such platforms have properties that make them well-suited to the visualization of very large datasets. They can represent the data with a high level of detail while at the same time retaining context: users can transition from an overview of the data to a detailed view simply by physically moving in front of the wall display. Wall displays also offer good support for collaborative work, enabling multiple users to simultaneously visualize and interact with the displayed data. To make them interactive, wall-sized displays are increasingly coupled with input devices such as touch frames, motion-tracking systems and wireless multitouch devices, in order to enable multi-device and multi-user interaction with the displayed data. Application areas for such visualization platforms range from the monitoring of complex infrastructures and crisis management situations to tools for the exploratory visualization of scientific data.

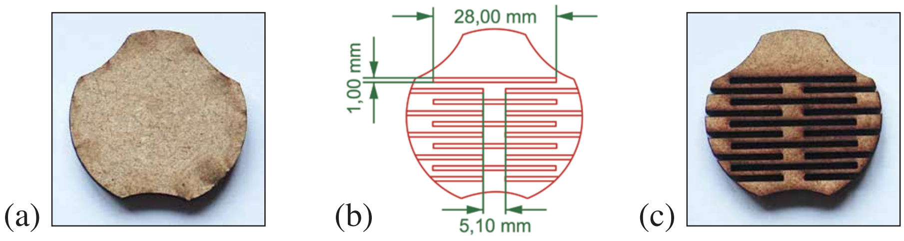
WILDER is the latest ultra-high-resolution wall-sized display set up at Inria Saclay, and is one of the nodes of the Digiscope EquipEx. We use this platform for multiple projects, both fundamental HCI research, and research and development activities for specific application areas such as geographical informations systems (Figure 2) and astronomy.

WILDER was used in the projects that led to the following publications this year: [22], [24], [18].

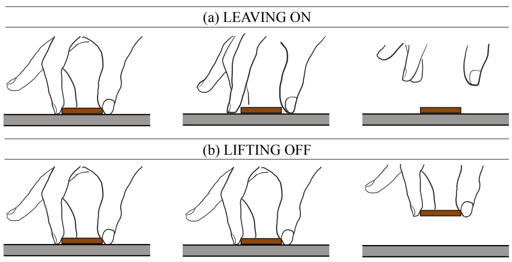
7. New Results

7.1. Gestures and Tangibles

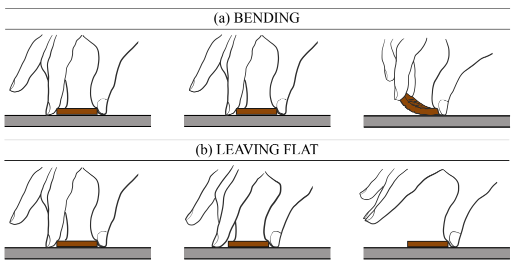
- As a follow-up to our work on TouchTokens [6], we investigated a way to augment the expressiveness of passive tokens for tangible interaction. This work was published at CHI 2017 [23]. TouchTokens are passive tokens that can be recognized on any capacitive surface based on the spatial configuration of the fingers that hold them. However, interaction with these tokens is confined to the basic two-state model of touch interaction as the system only knows the tokens' position and cannot detect tokens that are not touched. We increased the expressive power of TouchTokens by introducing laser-cut lattice hinges in their design, so as to make them flexible (Figure 3). A new recognizer, that analyzes the micro-movements of the fingers that hold the tokens, enables the system to detect when a token is left on the surface rather than taken off it. It can also detect bend events that can be mapped to command triggers, and a squeezed state that can be used for quasi-modal interaction.



Making a TouchToken flexible: (a) original, rigid TouchToken (circle, 4cm in diameter), (b) schematics of lattice-hinges, (c) flexible TouchToken.



Micro-movements when leaving a token *on* the surface (a), and when lifting it *off* (b)



Micro-movements when (a) bending a token, and when leaving it flat (b)

Figure 3. Flexible TouchTokens

- With MarkPad, presented at CHI 2017 [20] and demoed at IHM 2017, we propose a novel interaction technique taking advantage of the touchpad. MarkPad allows creating a large number of size-dependent gestural shortcuts that can be spatially organized as desired by the user. It relies on the idea of using visual or tactile marks on the touchpad or a combination of them. Gestures start from a mark on the border and end on another mark anywhere (see Figure 4). MarkPad does not conflict with standard interactions and provides a novice mode that acts as a rehearsal of the expert mode. A study showed that an accuracy of 95% could be achieved for a dense configuration of tactile and/or visual marks allowing 680 possible gestures, more than all existing techniques with a comparable input channel. Performance was 5% lower in a second study where the marks were only on the borders, and subjective results suggest that a mixed interface (borders with tactile marks and center with visual marks) is a promising solution. A working prototype is freely available at http://brunofruchard.com/markpad.html.

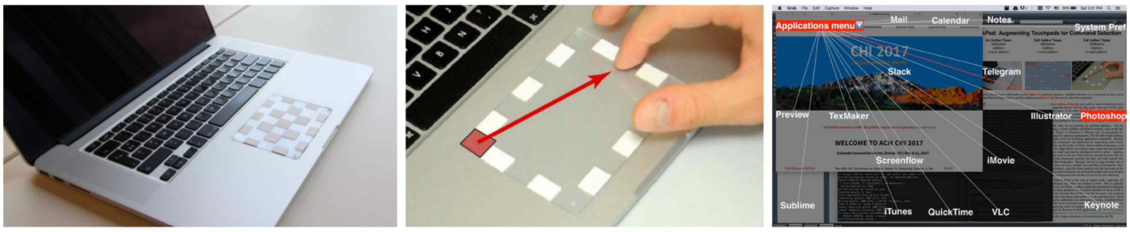


Figure 4. Tactile or visual marks on the touchpad help performing gestures: (Left) Dense configuration of tactile marks, (Middle) Light configuration with marks only on the borders, (Right) Example of a menu in novice mode. This menu and the selected shortcut on its right side correspond to the red area and the red gesture line in the middle picture.

7.2. Interacting with Linked Data and the Semantic Web

- As part of the team's novel research theme on Semantics-Driven Data Manipulation 3.2, Emmanuel Pietriga worked jointly with colleagues from Linköping University on a visualization technique for the comparative evaluation of ontology alignments produced by different algorithms, that was published at the International Semantic Web Conference [21]. Ontology alignment is an area of active research where many algorithms and approaches are being developed. Their performance is usually evaluated by comparing the produced alignments to a reference alignment in terms of precision, recall and F-measure. These measures, however, only provide an overall assessment of the quality of the alignments, but do not reveal differences and commonalities between alignments at a finer-grained level such as, e.g., regions or individual mappings. Furthermore, reference alignments are often unavailable, which makes the comparative exploration of alignments at different levels of granularity even more important. Making such comparisons efficient calls for a human-in-the-loop approach, best supported through interactive visual representations of alignments. Our approach extended previous work by Inria on Matrix Cubes [32], used for visualizing dense dynamic networks. We identified use cases for ontology alignment evaluation that could benefit from interactive visualization, and then detailed how *Alignment Cubes* could support interactive exploration of multiple ontology alignments. We then showed how alignment cubes could support common tasks identified in these use cases.

7.3. Wall Displays

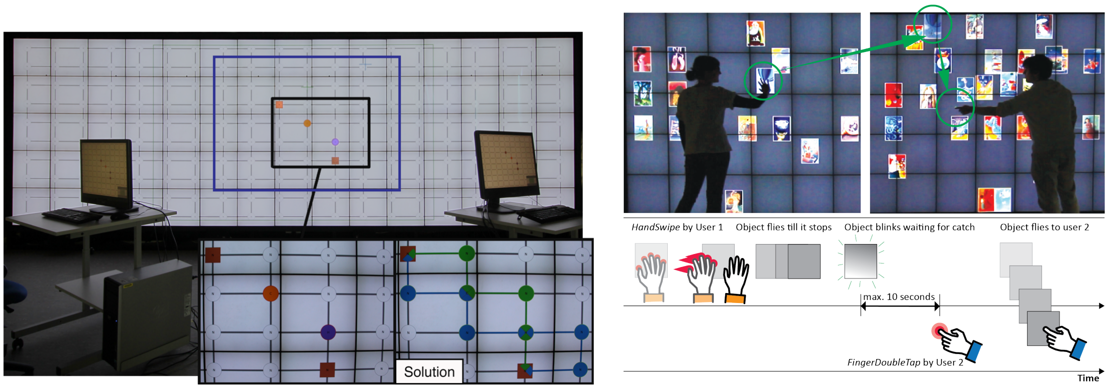


Figure 5. (Left) The setup for comparing a wall display with two desktops. Participants had to construct paths between the two brown nodes, that only crossed at the other colored nodes. The lower part of the image shows the closeup of a possible solution. (Right) An example of cooperative a gesture: throw-and-catch.

Ultra-high-resolution wall displays feature a very high pixel density over a large physical surface, which makes them well-suited to the collaborative, exploratory visualization of large datasets (see Section 6.3.1). We have continued working on the design, implementation and evaluation of interactive visualization techniques for such ultra-high-resolution wall-sized displays, focusing, in some of these projects, on the collaboration between users who perform different data manipulation and analysis tasks.

- We first studied if wall displays indeed provide advantages over more classic collaboration setups, such as multiple desktops [24]. Very few studies that empirically assess the differences of collaboration in front of a shared display compared to a non-shared setup, such as multiple desktops with a common view. We compared the use of the wall compared to two desktops, when pairs of users learn to perform a path-planning task (see Figure 5-(Left)). Path planning tasks are common in critical situations (e.g., rerouting resources). We focused on learning, to approach exceptional and unexpected events in critical systems. Our results did not indicate a significant difference in learning time between the two setups, but found that participants adopted different task strategies and that quality was more consistent in the wall setup.
- We also continued our work on shared interaction techniques (see [56]). Multi-touch wall-sized displays afford collaborative exploration of large datasets and re-organization of digital content. However, standard touch interactions, such as dragging to move content, do not scale well to large surfaces and were not designed to support collaboration, such as passing an object around. With *CoReach* [22], published at CHI 2017, we introduce a set of collaborative gestures that combine input from multiple users in order to manipulate content, facilitate data exchange and support communication (see Figure 5-(Right) for an example). We conducted an observational study to inform the design of *CoReach*, and a controlled study showing that it reduced physical fatigue and facilitated collaboration when compared with traditional multi-touch gestures. A final study assessed the value of also allowing input through a handheld tablet to manipulate content from a distance.
- We also studied more explicitly how interaction techniques affect collaboration. We investigated how pairs explore graphs on a touch enabled wall-display [18], using two selection techniques adapted for collaboration: a basic localized selection, and a propagation selection technique that uses the idea of diffusion/transmission from an origin node. Results from this work were accepted for publication in 2016 (and was part of the previews report), but the work appeared in print this year.

7.4. Visualization

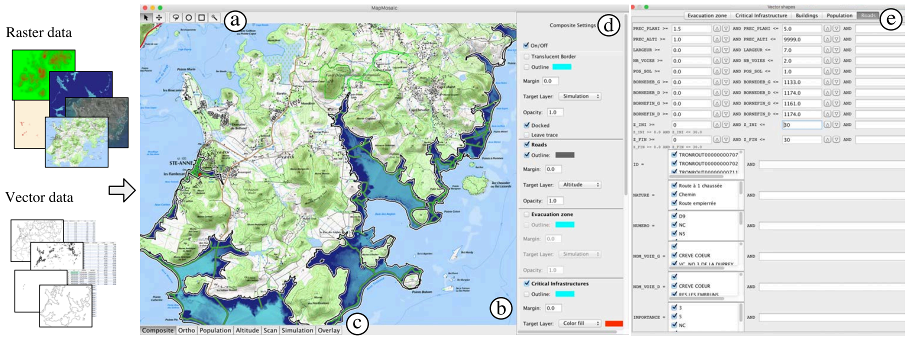


Figure 6. A proof-of-concept implementation of the MapMosaic dynamic compositing model and interaction techniques. (a) Toolbar to navigate the map, and to create & select areas. (b) Map viewer. (c) Access to individual layers. (d) Compositing area inspector. (e) Query builder for compositing region filters.

- In the context of ANR-funded collaborative project MapMuxing (see Section 9.2.1), we investigated novel dynamic map compositing techniques for geovisualization. GIS software applications and other mapping tools enable users to correlate data from multiple layers and gain insight from the resulting visualizations. However, most of these applications only feature basic, monolithic layer compositing techniques. These techniques do not always support users effectively in their tasks, as we observed during interviews with GIS experts at IGN (French national cartographic institute). We designed MapMosaic (Figure 6), a novel approach based on dynamic visual compositing that enables users to interactively create and manipulate local composites of multiple vector and raster map layers, taking into account the semantics and attribute values of objects and fields in the compositing process. We evaluated MapMosaic's interaction model against that of QGIS (a widely used desktop GIS) and MAPublisher (a professional cartography tool) using the Cognitive Dimensions framework, showing that MapMosaic's model is more flexible and can support users more effectively in their tasks. Feedback obtained from experts further confirmed the potential of this highly dynamic approach to map layer compositing.
- We also explored how different interactive visualizations of multidimensional datasets can affect how we make decisions [15]. We evaluated three elementary visualizations: parallel coordinates, scatterplot matrices and tabular visualizations. Our method consisted in first giving participants low-level analytic tasks, in order to ensure that they properly understood the visualizations and their interactions. Participants were then given multi-attribute choice tasks consisting of choosing holiday packages. We assessed decision support through multiple objective and subjective metrics, including a decision accuracy metric based on the consistency between the choice made and self-reported preferences for attributes. We found the three visualizations to be comparable on most metrics, with a slight advantage for tabular visualizations. In particular, tabular visualizations allow participants to reach decisions faster. Our results also suggest that indirect methods for assessing choice confidence may allow to better distinguish between visualizations than direct ones. Related to this topic, is our previous work on studying how biases can affect our decision making when using visualizations [14], work that was accepted in 2016 (and thus was part of last year's report) but appeared in print this year.
- Beyond the actual interactive visualizations themselves, we studied how framing the questions to participants may affect the results of evaluating visualizations [19]. More specifically we explored the effects of providing task context when evaluating visualization tools in crowdsourced studies. We gave participants abstract information visualization tasks without any context; tasks where we added

semantics to the dataset; and tasks with two types of backstory narratives: an analytic narrative and a decision-making narrative. We did not find evidence that adding data semantics increases accuracy, but that it increases attention and provides subjective benefits in terms of confidence, perceived easiness, task enjoyability and perceived usefulness of the visualization. Interestingly, we also found that backstory narratives, often used to motivate study participants, can even decrease accuracy.

- Finally, we are interested in understanding how people understand more general multidimensional visualisations. We mention here again work with colleagues both from University of Konstanz [16] on a review of multidimensional visualizations in the forms of glyphs; and with colleagues from INRA on a mixed initiative system that aids navigation of complex multi-dimensional datasets [41]. Both these results were accepted for publication in 2016 (and were part of the previous report), but the work appeared in print this year.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

- Tecknowmetrix (TKM): ANRT/CIFRE PhD (Hugo Romat), 3 years, starting June 2016.

9. Partnerships and Cooperations

9.1. Regional Initiatives

ScaleGest. Surface Gestures for Advanced Graphical Interfaces: Which Gesture for What. (2014-2017) Funded by Digiteo. In collaboration with Telecom ParisTech: **109Keuros**. Participants: Caroline Appert (PI), Rafael Morales Gonzalez, Emmanuel Pietriga.

The project aims at designing gesture-based interaction for expert users who navigate and manipulate large datasets. In the context of advanced graphical applications, the number of gestures should be large-enough to cover the set of controls (*i.e.*, commands and parameter settings) but remain simple-enough to avoid exceeding human abilities. Making gesture-based interaction scale with graphical applications' growing complexity can be achieved only by understanding the foundational aspects of this input modality. This project is about characterizing and structuring both the space of application controls and the space of surface gestures in order to establish guidelines for appropriate control-gesture mappings. It is also about the definition of a sound and systematic evaluation methodology that will serve as a reference benchmark for evaluating these mappings. The resulting control-gesture mappings are demonstrated in the specific application domains of cartography and astronomy.

9.2. National Initiatives

9.2.1. ANR

MapMuxing - Multi-dimensional Map Multiplexing. (2014-2018) Funded by the French National Research Agency (ANR). In collaboration with IGN (Institut National de l'Information Géographique et Forestière): **208Keuros**/499Keuros. Participants: Emmanuel Pietriga (PI), Caroline Appert, Olivier Chapuis, Maria Jesus Lobo Gunther, Vit Rusnak. http://mapmuxing.ign.fr

The project explores novel ways of combining different maps and data layers into a single cartographic representation, and investigates novel interaction techniques for navigating in it. The project aims at going beyond the traditional pan & zoom and overview+detail interface schemes, and at designing and evaluating novel cartographic visualizations that rely on high-quality generalization, *i.e.*, the simplification of geographic data to make it legible at a given map scale, and symbol specification.

9.2.2. Inria - Ministère de la Culture

Visual Exploration of Linked Data on BnF's data portal (2017-2018) Funded by the French Ministère de la Culture and Inria. **65Keuros**. Participants: Emmanuel Pietriga (PI), Caroline Appert, Hande Gözükan, Marie Destandau, Dylan Lebout.

The project explores novel ways of visually navigating the data exposed by the Bibliothèque Nationale de France as linked data on http://data.bnf.fr.

9.2.3. Inria Project Lab

ILDA participates to Inria Project Lab iCODA : Data Journalism : knowledge-mediated Content and Data Interactive Analytics, that started in 2017. A key issue in data science is the design of algorithms that enable analysts to infer information and knowledge by exploring heterogeneous information sources, structured data, or unstructured content. With journalism data as a landmark use-case, iCODA aims to develop the scientific and technological foundation for collaborative, heterogeneous data analysis, guided by formalized, user-centric knowledge. The project relies on realistic scenarios in data-journalism to assess the contribution of the project to this area. iCODA is at the crossroads of several research areas (content analysis, data management, knowledge representation, visualization) and is part of a club of partners of the world of the press. Equipes-projets Inria : Graphik, Ilda, Linkmedia, Cedar. Press partners: Le Monde, OuestFrance, AFP. Participants: Anastasia Bezerianos (PI) and Emmanuel Pietriga.

9.3. European Initiatives

9.3.1. Collaborations with Major European Organizations

- Deutsches Elektronen-Synchrotron (DESY): Scientific collaboration on the design and implementation of user interfaces for array operations monitoring and control for the Cherenkov Telescope Array (CTA) project, to be built in the Canary Islands (Spain) and in the Atacama desert (Chile).

9.4. International Initiatives

9.4.1. Inria International Labs

Inria Chile / CIRIC. From 2012 to 2015, Emmanuel Pietriga was the scientific leader of the Massive Data team at Inria Chile, working on projects in collaboration with the ALMA radio-telescope and the Millenium Institute of Astrophysics. He is now scientific advisor to Inria Chile's visualization lab, and is actively involved in the collaboration between Inria Chile and the LSST on the design and development of user interfaces for operations monitoring and control.

9.4.2. Inria International Partners

9.4.2.1. Informal International Partners

- KISTI (Korea). 2017. We investigated the potential of ultra-high-resolution wall-sized displays for the visualization of stream IOT data in the field of air quality monitoring in large and dense urban areas in Korea. The goal of the project was to design and implement an interactive multi-scale visualization of streamed data collected from vehicles (taxis) equipped with a battery of sensors and geolocation devices. The project focused on how to design effective visualizations that take advantage of the specific characteristics of large surfaces featuring a very high pixel density ; and on how to handle streams of IOT data, in this case the sensor data from all taxis, both live data streams and historical data retrieved from a database.
- University of Konstanz: Daniel Keim and Johannes Fuchs on mapping out the design space for visualization glyphs [16]. Participants: Anastasia Bezerianos.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Iftach Sadeh, DESY/CTA Observatory, February 2017

9.5.1.1. Internships

- María Grazia Prato, Inria Chile, October 2017
- Amanda Ibsen, Sebastian Pereira, María Grazia Prato, Inria Chile, June 2017

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

- EICS 2018, 10th ACM SIGCHI Symposium on Engineering Interactive Computing Systems: Emmanuel Pietriga (general co-chair)
- CHI 2017, 35th ACM SIGCHI Conference on Human Factors in Computing Systems: Caroline Appert (papers co-chair)

10.1.1.2. Member of the Organizing Committees

- VIS 2017, the IEEE Visualization Conference (SciVis, InfoVis, VAST): Anastasia Bezerianos (Communities co-chair)

10.1.2. Scientific Events Selection

10.1.2.1. Chair of Conference Program Committees

- CHI 2018, 36th ACM SIGCHI Conference on Human Factors in Computing Systems: Emmanuel Pietriga (SC - subcommittee chair)

10.1.2.2. Member of the Conference Program Committees

- CHI 2018, 36th ACM SIGCHI Conference on Human Factors in Computing Systems: Anastasia Bezerianos
- UIST 2017, 30th ACM User Interface Software and Technologies Symposium: Anastasia Bezerianos
- InfoVis 2017, the IEEE Visualization Conference (SciVis, InfoVis, VAST): Anastasia Bezerianos
- WWW 2018, 27th Web Conference, research track Web Content Analysis, Semantics, and Knowledge: Emmanuel Pietriga
- ISWC 2017, 16th International Semantic Web Conference: Emmanuel Pietriga
- EICS 2017, 9th ACM SIGCHI Symposium on Engineering Interactive Computing Systems: Emmanuel Pietriga
- VOILA @ ISWC 2017, Visualizations and User Interfaces for Ontologies and Linked Data, workshop co-located with ISWC 2017: Emmanuel Pietriga
- Immersive Analytics @ InfoVis 2017: Exploring Future Interaction and Visualization Technologies for Data Analytics, workshop co-located with IEEE InfoVis 2017: Emmanuel Pietriga, Anastasia Bezerianos

10.1.2.3. Reviewer

- ACM CHI 2018, Conference on Human Factors in Computing Systems: Caroline Appert, Olivier Chapuis, Bruno Fruchard, Maria Jesus Lobo Gunther, Arnaud Prouzeau
- ACM UIST 2017, Symposium on User Interface Software and Technology: Caroline Appert, Olivier Chapuis
- ACM ISS 2017, International Conference on Interactive Surfaces and Spaces: Olivier Chapuis

- ACM TEI 2017, International Conference on Tangible, Embedded and Embodied Interaction: Caroline Appert, Bruno Fruchard (WiP), Vit Rusnak (WiP)
- ACM MobileHCI 2017 , International Conference on Human-Computer Interaction with Mobile Devices and Services: Caroline Appert
- GI 2017, Graphics Interface: Olivier Chapuis, Arnaud Prouzeau
- Graph Drawing 2017: Emmanuel Pietriga
- EuroVis EG/VGTC 2017, Conference on Data Visualization: Anastasia Bezerianos
- OzCHI 2017: Vit Rusnak
- IHM 2017, Conference of the Association Francophone d'Interaction Homme-Machine: Olivier Chapuis

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- ACM ToCHI, Transactions on Computer-Human Interaction: Caroline Appert

10.1.3.2. Reviewer - Reviewing Activities

- ACM ToCHI, Transactions on Computer-Human Interaction: Olivier Chapuis
- IEEE TVCG, Transactions on Visualization and Computer Graphics: Olivier Chapuis, Emmanuel Pietriga, Caroline Appert, Anastasia Bezerianos
- IEEE Pervasive Computing: Emmanuel Pietriga
- Future Generation Computer Systems: Vit Rusnak

10.1.4. Invited Talks

- Emmanuel Pietriga and Olivier Chapuis: Monitoring Air Quality in Korea's Metropolises on Ultra-High Resolution Wall-Sized Displays, Asia Data Week 2017, Jeju, South Korea, November 2017
- Caroline Appert: Reconnaître un pattern de points de contact sur une surface tactile – *Multi-Touch* et *Machine Learning*, Journée IHM-IA, Paris (UPMC), France, March 2017.
- Anastasia Bezerianos: Concepts of Information Visualization research, and ties to Data Management, DBTrento, University of Trento, Italy, November 2017.

10.1.5. Leadership within the Scientific Community

- ANR, CES Vice chair - Interaction, Robotique: Caroline Appert

10.1.6. Scientific Expertise

- H2020, Leadership in Enabling and Industrial Technologies - Space RIA: Emmanuel Pietriga
- ANR, CES Vice chair - Interaction, Robotique: Caroline Appert

10.1.7. Research Administration

- Deputy Director of the Laboratoire de Recherche en Informatique (LRI): Olivier Chapuis
- President of Inria Saclay - Île de France's Commission for Technological Development (CDT): Emmanuel Pietriga

10.1.8. Learned societies

- Association Francophone d'Interaction Homme-Machine (AFIHM), in charge of the relation with the SIF: Olivier Chapuis.
- SigCHI Paris Local Chapter, chair: Anastasia Bezerianos.
- SigCHI Paris Local Chapter, vice chair: Caroline Appert.

10.1.9. Hiring committees

- Univ. Paris-Sud hiring committee, Commission Consultative des Spécialistes de l'Université 27ème section (computer science), members: Caroline Appert.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master: Anastasia Bezerianos, Head of EIT masters M1 & M2 HCID, Univ. Paris-Sud

Master: Anastasia Bezerianos, Head of M2 Interaction, Univ. Paris-Sud, Université Paris-Saclay

Master: Anastasia Bezerianos, Programming of Interactive Systems – 21h CM, M1/M2 HCID + M2R Interaction, Univ. Paris-Sud

Master: Anastasia Bezerianos, Mixed Reality and Tangible Interaction – 11h CM, M1/M2 HCID + M2R Interaction, Univ. Paris-Sud

Master: Anastasia Bezerianos, Career Seminar, – 12h CM, M2 HCID + M2R Interaction, Univ. Paris-Sud

Master: Anastasia Bezerianos, Design Project in HCI, – 21h CM, M1 HCID, Univ. Paris-Sud

Master: Anastasia Bezerianos, HCI Project, – 21h CM, M2 HCID + M2 Interaction, Univ. Paris-Sud

Master: Anastasia Bezerianos, Introduction to Java – 18h CM, M1/M2 HCID + M2R Interaction, Univ. Paris-Sud

Master: Emmanuel Pietriga, Data Visualization, 24h CM, M2 Informatique Décisionelle, Univ. Paris-Dauphine.

Master: Caroline Appert, Evaluation of Interactive Systems, 21h CM, M2 Interaction Univ. Paris-Sud / M1-M2 HCID EIT Digital.

Master: Caroline Appert, Advanced Evaluation of Interactive Systems, 21h CM, M2 Interaction Univ. Paris-Sud / M1-M2 HCID EIT Digital.

Master: Arnaud Prouzeau, Programmation des interfaces interactives avancées, 27h, M1 Info Univ. Paris-Sud

Licence: Maria Jesus Lobo Gunther, Algorithmique Informatique Graphique, 27h, L3 Univ. Paris-Sud

Licence: Maria Jesus Lobo Gunther, Programmation des interfaces interactives avancées, 27h, L3 Univ. Paris-Sud

Licence: Maria Jesus Lobo Gunther, Interaction Homme-Machine, 12h TP, L3 Polytech Paris Sud

Licence: Arnaud Prouzeau, Interaction Homme-Machine, 12h TP, L3 Polytech Paris Sud

Licence: Arnaud Prouzeau, Programmation Impérative Avancée en C++, 16.5h TP, L1 MPI, Université Paris-Sud

Licence: Bruno Fruchard, Visualisation, 10h, Télécom Paristech.

Licence: Bruno Fruchard, Interaction Homme-Machine, 16h, Télécom Paristech.

Licence: Bruno Fruchard, Paradigmes de programmation, 12h, Télécom Paristech.

Licence: Bruno Fruchard, Infrastructures et plateformes pour l'informatique répartie, 34h, Télécom Paristech.

10.2.2. Supervision

PhD : Maria Jesus Lobo Gunther, Interaction Techniques for Map Multiplexing, defended on December 5th, 2017. Advisors: Caroline Appert, Emmanuel Pietriga

PhD : Rafael Morales Gonzalez, Surface Gestures for Advanced Graphical Interfaces: Which Gesture for What, defended on October 4th, 2017. Advisors: Caroline Appert, Gilles Bailly, Emmanuel Pietriga

PhD : Arnaud Prouzeau, Collaboration around Wall-Displays in Time Critical and Command and Control Contexts, defended on December 15th, 2017. Advisors: Anastasia Bezerianos, Olivier Chapuis

PhD : Evanthia Dimara, Merging Interactive Visualization and Automated Analysis for Group Decision-Making Involving Large Datasets, defended on November 30th, 2017, Advisors: Pierre Dragicevic, Anastasia Bezerianos

PhD in progress : Marie Destandau, Interactive Visual Exploration of Webs of Data, since October 2017, Advisors: Caroline Appert, Emmanuel Pietriga

PhD in progress : Anna Gogolou, Iterative and expressive querying for big data series, October 2016, Advisors: Anastasia Bezerianos, Themis Palpanas

PhD in progress : Hugo Romat, Visual exploration and interactive manipulation techniques for collections of heterogeneous data and documents, since June 2016, Advisors: Caroline Appert, Emmanuel Pietriga

PhD in progress : Bruno Fruchard, Techniques d'interaction exploitant la mémoire spatiale pour faciliter l'accès rapide aux commandes et aux données, since October 2015, Advisors: Eric Lecolinet, Olivier Chapuis

Master (M2): Dylan Lebout, Visualization of geolocated and temporal data on the Web , May - September 2017, Advisors: Caroline Appert, Emmanuel Pietriga

Master (M2): Reyhaneh Raissi, Multi-user Multi-selection on Tabletop, Mars - September 2017, Advisors: Anastasia Bezerianos, Olivier Chapuis

Master (M1): Eleonore Bartenlian, Tools for customizing tangible interfaces, May - July 2017, Advisors: Caroline Appert

10.2.3. Juries

HDR: Guillaume Touya (IGN/Université Paris-Est): Emmanuel Pietriga (examinateur)

PhD: Justin Mathew (Inria/Université Paris-Saclay): Emmanuel Pietriga (président du jury)

PhD: Lonni Besançon (Inria/Université Paris-Saclay): Emmanuel Pietriga (président du jury)

PhD: Hanaë Rateau (Inria/Université Lille 1): Caroline Appert (examinateur)

PhD: Maxime Guillon (Université Grenoble Alpes): Caroline Appert (examinateur)

PhD: Antoine Lhuillier (ENAC/Université Toulouse III): Caroline Appert (examinateur)

10.3. Popularization

- *Fête de la science*, Université Paris-Sud: Caroline Appert.
- *Science en Direct*, Cité de la Science: Maria Jesus Lobo Gunther.
- *Qu'est-ce qu'un chercheur en IHM ?*, to high-school students visiting Telecom ParisTech: Bruno Fruchard.

11. Bibliography

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Doctoral Dissertations and Habilitation Theses

[11] C. APPERT. *From Direct manipulation to Gestures: Moving the Expressive Power from the Displays to the Fingers*, Paris-Sud XI, June 2017, Habilitation à diriger des recherches, https://tel.archives-ouvertes.fr/tel-01557524

Articles in International Peer-Reviewed Journals

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