Activity Report 2012

Team POTIOC

Popular interaction with 3d content

RESEARCH CENTER
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THEME
Interaction and Visualization

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Team POTIOC

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2. Overall Objectives

2.1. Overall Objectives

The overall objective of Potioc is to **open 3D digital worlds** [1] **to everyone** with the ultimate goal of stimulating creation, communication, understanding, or entertainment. To this end, we propose to focus on the **design**, **development** and **evaluation** of **3D User Interfaces** (UI), mostly targeted at the general public. In other words, we aim at designing **popular** 3D interfaces.

Printing, photography, Internet, are examples of technologies that have changed the way people communicate together, understand, create, or get entertainment. At the beginning, these technologies were dedicated to expert users, then they have become available to all, contributing to the fulfillment of anyone. Today, 3D digital worlds could play a similar role, but they tend to be used only by a limited number of highly trained people. Our motivation is to democratize such 3D technologies for favoring communication, understanding, creation, or entertainment for anyone.

[1] A 3D digital world can be defined as a 3D data space with which one can interact in real-time, the display of such data being either monoscopic or stereoscopic. For instance, a city that has been modeled in 3D, in which a user can navigate using a joystick is a 3D digital world. On the contrary, a 3D movie for which the user remains a passive viewer does not belong to this category.

Figure 1. Example of a 3D user interface where a child manipulates a 3D scene projected on a sheet of paper to prepare a drawing. Palais de la découverte, Paris, Nov. 2011 (see [17] for details).

For example, in the scope of learning, it can be difficult for a child to understand how molecules can assemble together from a drawing on a piece of paper, as classically done in school. We can presume that, with a 3D visualization of the molecules, the understanding of the data can be improved. Beyond a 3D visualization, it will be particularly important for the child to manipulate the molecules to understand how they fit together. Indeed, perception and action are extremely linked, as it has been shown by Berthoz. By being active in the process of interactive visualization, the implication of the child will be increased and, consequently, the learning process will be favored. Such an example requires the completion of complex interaction tasks for which it does not exist any standard solution. Numerous research questions are thus linked to such a challenge, and this is what we want to address in Potioc.

To reach this goal, we will focus on the interaction aspect, which we consider as the main barrier for increasing the adoption of 3D digital worlds by all. Indeed, without a proper interface, users would not be able or would not want to use 3D digital worlds. We will address 3D interaction tasks such as navigation in 3D environments, manipulation of 3D objects, exploration of volumes, and so on. The conception of relevant user interfaces for completing such tasks implies tackling at the same time motor, perceptive, and cognitive aspects, at different levels: hardware, software, and at a user level. In Potioc, we will follow a multi-disciplinary approach where our research and development works will be arranged according to the following three main axes:

- Exploring and enhancing input/output interaction space
- Designing targeted interaction techniques
- Understanding and assessing user interaction

We will not focus on one specific technology. Instead, we will benefit from the wide input and output space that is available today, with a special interest for emerging technologies. In particular, we will consider both technologies that are able to detect motor activities, i.e., physical actions of the user (e.g. joysticks, multitouch surfaces and 3D spatial technologies) and interfaces measuring and interpreting the physiological signals of the user, i.e., non-motor activities of the user. This notably includes Brain-Computer Interfaces (BCI) [2], which provide a unique way to access the users' mental states, thus opening the door to many promising applications

[2]Brain-Computer Interface are devices that enable its users to interact with computers by mean of brain-activity only, this brain activity being measured (generally by ElectroEncephaloGraphy (EEG)) and processed by the system. A typical example of a BCI would a system in which a user could move an object on screen towards the left or right, by imagining movement of his left or right hand, respectively.

and tools that tap into this new kind of input, unavailable to other interfaces. We will also explore various output spaces, including large-scale visualization, stereoscopic visualization, or tangible approaches.

Based on this rich interaction space, we will design interaction techniques dedicated to the completion of 3D interaction tasks. In this part of this project, we will put aside hardware considerations to concentrate on the software part of the UIs. Such interaction techniques will target users that are not expert in 3D interaction. In particular, we will concentrate on the general public, specialists with no expertize in 3D, and people with impairments.

Finally, a large part of the project will be dedicated to human factors for understanding and for evaluating user interaction. In particular, we will conduct experiments *a-priori* to guide our developments and *a-posteriori* to assess them. We will also explore passive BCI to better evaluate 3D interaction.

Previous developments tended to be driven by criteria of speed, efficiency or precision for industrial purposes. These criteria, which are very important in domains where profitability is crucial, may not be the most fundamental ones in our project where the approach is to increase the intrinsic motivation of non-expert users. Therefore, in Potioc, we will emphasize criteria such as appeal and enjoyment, which have been scarcely taken into account in the past. Indeed, we believe that non-expert users need pleasant and enjoyable interfaces to adopt 3D digital worlds, in the scope of education, art, health care, or entertainment.

3. Scientific Foundations

3.1. Introduction

The design of new user interfaces is a complex process that requires tackling research challenges at different levels. First, at a technological level, the input and output interaction space is becoming richer and richer. We will explore the new input/output modalities offered by such a technological evolution, and we will contribute to extend these modalities for the purpose of our main objective, which is to make 3D digital worlds available to all. Then, we will concentrate on the design of good interaction techniques that rely on such input/output modalities, and that are dedicated to the population targeted by this project, i.e. general public, specialists which are not 3D experts, and people with impairments. Finally, a large part of our work will be dedicated to the understanding and the assessment of user interaction. In particular, we will conduct user studies to guide the design of hardware and software UI, to evaluate them, and to better understand how a user interacts with 3D environments.

These three levels, input/output modalities, interaction techniques, and human factors will be the three main research directions of Potioc. Of course, they are extremely linked, and they cannot be studied independently, one after the other. In particular, user studies will follow the design process of hardware/software user interfaces from the beginning to the end, and both hardware and software exploration will be interdependent. The design of a new 3D user interface will thus require some work at different levels, as illustrated in Figure 2. All members of Potioc will contribute in each of these research directions.

3.2. Exploring and enhancing input/output interaction space

The Potioc project-team will be widely oriented towards new innovative input and output modalities, even if standard approaches based on keyboard/mouse and standard screens will not be excluded. This includes motor-based interfaces, and physiological interfaces like BCI, as well as stereoscopic display and augmented reality setups. These technologies may have a great potential for opening 3D digital worlds to anyone, if they are correctly exploited.

We will explore various input/output modalities. Of course, we will not explore all of them at the same time, but we do not want to set an agenda either, for focusing on one of them. For a given need fed by end-users, we will choose among the various input/output modalities the ones that have the biggest potential. In the following paragraphs, we explain in more details the research challenges we will focus on to benefit from the existing and upcoming technologies.

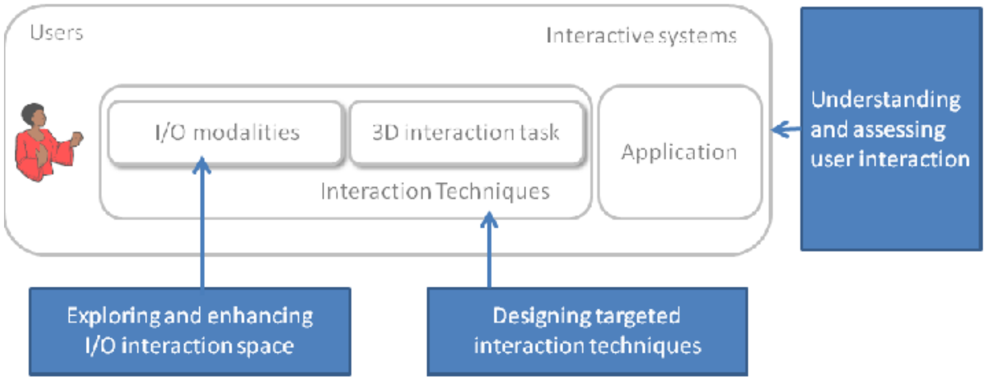

Figure 2. Diagram of an interactive system and the three main research axes of the Potioc project (blue boxes).

3.2.1. Real-time acquisition and signal processing

There is a wide number of sensors that can detect users' activity. Beyond the mouse that detects x and y movements in a plane, various sensors are dedicated to the detection of 3D movements, pressure, brain and physiological activity, and so on. These sensors provide information that may be very rich, either to detect command intent from the user or to estimate and understand the user's state in real-time, but that are difficulty exploitable as it. Hence, a major challenge here is to extract the relevant information from the noisy raw data provided by the sensor.

An example, and important research topic in Potioc, is in the analysis of brain signals for the design of BCI. Indeed, brain signals are usually measured by EEG, such EEG signals being very noisy, complex and non-stationary. Moreover, for BCI-based applications, they need to be processed and analyzed in real-time. Finally, EEG signals exhibit large inter-user differences and there are usually few examples of EEG signals available to tune the BCI to a given user (we cannot ask the user to perform thousands of time the same mental task just to collect examples). As such, appropriate signal processing algorithms must be designed in order to robustly identify EEG patterns reflecting the user's intention. The research challenges are thus to design algorithms with high performance (in terms of rate of correctly identify user's state) anytime, anywhere, that are fully automatic and with minimal or no calibration time. In other words, we must design BCI that are convenient, comfortable and efficient enough so that they can be accepted and used by the end-user. Indeed, most users, in particular healthy users in the general public are used to highly convenient and efficient input devices (e.g., a simple mouse) and would not easily tolerate systems with a lower performance. Achieving this would make BCI good enough to be usable outside laboratories, e.g., for video gamers or patients. This will also make BCI valuable and reliable evaluation tools, e.g., to understand users' state during a given task. To address these challenges, pattern recognition and machine learning techniques are often used in order to find the optimal signal processing parameters. Similar approaches may contribute to the analysis of signals coming from other input devices than BCI. An example is the exploitation of depth cameras, where we need to find relevant information from noisy signals. Other emerging technologies will require similar attention, where the goal will be to transform an unstructured raw signal into a set of higher level descriptors that can be used as input parameters for controlling interaction techniques.

3.2.2. Restitution and perceptive feedback

Similarly to the input side, the feedback provided to the user through various output modalities will be explored in Potioc. Beyond the standard screens that are commonly used, we will explore various displays. In particular, in the scope of visual restitution, we will notably focus on large screens and tables, mobile setups and projection on real objects, and stereoscopic visualization. The challenge here will be to conceive good visual metaphors dedicated to these unconventional output devices in order to maximize the attractiveness and the pleasure linked to the use of these technologies.

For example, we will investigate the use of stereoscopic displays for extending the current visualization approaches. Indeed, stereoscopic visualization has been little explored outside the complex VR setups dedicated to professional users. We believe that this modality may be very interesting for non-expert users, in wider contexts. To reach this goal, we will thus concentrate on new visual metaphors that benefit from stereoscopic visualization, and we will explore how, when, and where stereoscopy may be used.

Depending on the targeted interaction tasks, we may also investigate various additional output modalities such as tangible interaction, audio displays, and so on. In any case, our approach will be the same, which is understanding how new perceptive modalities may push the frontier of our current interactive systems.

3.2.3. Creation of new systems

In addition to the exploration and the exploitation of existing input and output modalities for enhancing interaction with 3D content, we may also contribute to extend the current input/output interaction space by building new interactive systems. This will be done by combining hardware components, or by collaborating with mechanics/electronics specialists.

3.3. Designing targeted interaction techniques

In the previous section, we focused on the input/output interaction space, which is closely related to hardware components. In this part, we focus on the design of interaction techniques, which we define here as the mean through which a user will complete an interaction task from a given interaction space. Even if this is naturally also linked to the underlying hardware components, the research conducted in this axis of the project will mainly concern software developments.

Similar to the input/output interaction space, the design of interaction techniques requires focusing on both the motor and the sensory components. In our 3D spatial context, thus the challenges will be to find good mappings between the available input and the DOF that need to be controlled in the 3D environment, and to provide relevant feedback to users so that they can understand well what they are doing.

The design of interaction techniques should be strongly guided by the targeted end-users. For example, a 3D UI dedicated to an expert user will not suit a novice user, and the converse is also true. In Potioc, where the final goal is to open 3D digital worlds to anyone, we will concentrate on the general public, specialists that are not 3D experts, and people with impairments.

3.3.1. General public

3D UIs have mainly been designed for professional use. For example, modeling tools require expertize to be used correctly and, consequently, they exclude the general public from the process of creating 3D content. Similarly, immersive technologies have been dedicated to professional users for a long time. Therefore, immersive 3D interaction techniques have generally been thought for trained users, and they may not fit well with a general public context. In Potioc, an important motivation will be to re-invent 3D UIs to adapt them to the general public. This motivation will guide us towards new approaches that have been little explored until now. In particular, to reach our objective, we will give a strong importance to the following criteria:

- Intuitiveness: a very short learning curve will be required.
- Enjoyability: this is needed to motivate novice users in the complex process of interaction with 3D content.
- Robustness: the UIs should support untrained users that may potentially interact with unpredictable actions.

In addition, we will keep connected with societal and technological factors surrounding the general public. For example, [multi]touch-screens have become very popular these past few years, and everyone tend to be familiar with a standard gesture vocabulary (e.g. pinch gestures and flicking gestures). We will rely on these commonly acquired *way-of-interact* to optimize the acceptability of the 3D UIs we will design. In this part of the project the challenge will be to conceive 3D UIs that offer a high degree of interactivity, while ensuring an easy access to technology, as well as a wide adherence.

3.3.2. Specialists

General public will be one of the main targets of Potioc for the design of 3D UIs. However, we do not exclude specialists, who have little experience with 3D interaction. These specialists can be for example artists, archaeologists, or architects. In any case, we are convinced that 3D digital worlds could benefit to such categories of users if we propose dedicated 3D UIs that allows them to better understand, communicate, or create, with their respective skills. Because such specialists will gain expertize while interacting with 3D content, it will be necessary to design 3D UIs that can adapt to their evolving level of expertize. In particular, the UIs should be easy to use and attractive enough to encourage new users. At the same time, they should provide advanced features that the specialist can discover while gaining expertize.

3.3.3. People with impairments

While the general public has been only scarcely considered as a potential target audience for 3D digital worlds, another category of users is even more neglected: people with impairments. Indeed, such people, in particular those with motor impairments, are unable to use classical input devices, since they have been designed for healthy users. People with motor impairment have to use dedicated input devices, adapted to their disabilities, such as a single switch. Since such input devices usually have much fewer degrees of freedom than classical devices, it is necessary to come up with appropriate interaction techniques in order to efficiently use this limited number of DOF to still enable the user to perform complex tasks in the 3D environment. In Potioc, our focus will be on the use of BCI to enable motor impaired users to interact with 3D environment for learning, creation and entertainment. Indeed, BCI enable a user to interact without any motor movement.

3.4. Understanding and assessing user interaction

The exploration of the input/output interaction space, and the design of new interaction techniques, are strongly linked with human factors, which will be the third research axis of the Potioc project. Indeed, to guide the developments described in the previous sections, we first need to well understand users' motor and cognitive skills for the completion of 3D interaction tasks. This will be explored thanks to *a-priori* experiments. In order to evaluate our hardware and software interfaces, we will conduct *a-posteriori* user studies. Finally, we will explore new approaches for a real-time cognitive analysis of the performance and the experience of a user interacting with a 3D environment.

The main challenge in this part of the project will be to design good experimental protocols that will allow us to finely analyze various parameters for improving our interfaces. In 2D, there exist many standard protocols and prediction laws for evaluating UIs (e.g. Fitts law and ISO 9241). This is not the case in 3D. Consequently, a special care must be taken when evaluating interaction in 3D spatial contexts.

In addition to the standard experiments we will conduct in our lab, we will conduct large scale experiments thanks to the strong collaboration we have with the center for the widespread of scientific culture, Cap Sciences (see Collaboration section). With such kind of experiments, we will be able to test hundreds of participants, with various ages, gender, or level of expertize that we will be able to track thanks to the Navinum system [3], and this during long period of time. A challenge for us will be to gain benefit from this wealth of information for the development of our 3D UIs.

[3] Navinum is a system based on a RFID technology that is used to collect informations about the activity of the visitors in Cap Sciences. http://www.scribd.com/doc/55178878/Dossier-de-Presse-Numerique-100511

3.4.1. A-priori user studies

Before designing 3D UIs, it is important to understand what a user is good at, and what may cause difficulties. This is true at a motor level, as well as a cognitive level. For example, are users able to coordinate the movements of several fingers on a touchscreen at the same time, or are they able to finely control the quantity of force applied on it while moving their hand? Similarly, are the users able to mentally predict a 3D rotation, and how many levels of depth are they able to distinguish when visualizing stereoscopic images? To answer these questions, we will conduct preliminary studies.

Our research in that direction will guide our developments for the other research axes described above. For example, it will be interesting to explore touch-based 3D UIs that take into account several level of force if we see that this parameter can be easily handled by users. On the other hand, if the results of a-priori tests show that this input cannot be easily controlled, then we will not push forward that direction.

The members of Potioc have already conducted such kinds of experiments, and we will continue our work in that direction. For some investigations, we will collaborate with psychologists and experts in cognitive sciences (see Collaborations section) to explore in more depth motor and cognitive human skills.

A-priori studies will allow us to understand how users tend to "*naturally*" interact to complete 3D interaction tasks, and to understand which feedback are the best suited. This will be a first answer to our global quest of providing pleasant interfaces. Indeed, this will allow us to adapt the UIs to the users, and not the opposite. This should enhance the global acceptability and motivation of users facing a new interactive system.

3.4.2. A-posteriori user studies

In Potioc, we will conceive new hardware and software interfaces. To validate these UIs, and to improve them, we will conduct user experiments, as classically done in the field of HCI. This is a standard methodology that we currently follow (see Bibliography). We will do this in our lab, and in Cap Sciences.

Beyond the standard evaluation criteria that are based on performance for speed, accuracy, coordination, and so on, we will also consider other criteria that are more relevant for the Potioc project. Indeed, we will give a great importance to enjoyability, pleasure of use, accessibility, and so on. Consequently, we will need to redefine the standard way to evaluate UIs. Once again, our relationship with Cap Sciences will help us in such investigations. The use of questionnaires will be a way to better understand how an interface should be designed to reach a successful use. In addition, we will observe and analyze how visitors tend to interact with various interfaces we will propose. For example, we will collect information like the time spent on a given interactive system or the number of smiles recorded during an interaction process. The identification of good criteria to use for the evaluation of a popular 3D UI will be one of the research directions of our team.

Conducting such *a-posteriori* studies, in particular with experts of mediation, with new criteria of success, will be a second answer to our goal of evaluating the pleasure linked to the use of 3D UIs.

3.4.3. Real-time cognitive analysis

Classically, the user's subjective preferences for a given 3DUI are assessed using questionnaires. While these questionnaires provide important information, this is only a partial, biased, a-posteriori/a-priori measure, since they are collected before or after the 3D interaction process. When questionnaires are administered during 3D interaction, this interrupts and disturbs the user, hence biasing the evaluation. Moreover, while evaluating performance and usefulness is now well described and understood, evaluating the user's experiance and thus the system usability appears as much more difficult, with a lack of systematic and standard approaches. Ideally, we would like to measure the user response and subjective experience while he/she is using the 3DUI, i.e., in real-time and without interrupting him/her, in order to precisely identify the UI pros and cons. Questionnaires cannot provide such a measure.

Fortunately, it has been recently shown that BCI could be used in a passive way, to monitor the user's mental state. More precisely, recent results suggested that appropriately processed EEG signals could provide information about mental states such as error perception, attention or mental workload. As such, BCI are emerging as a new tool to monitor a user's mental state and brain responses to various stimuli, in real-time. In the Potioc project, we propose a completely new way to evaluate 3DUI: rather than relying only on questionnaires to estimate the user's subjective experience, we propose to exploit passive BCI to estimate the user's mental state in real-time, without interrupting nor disturbing him or her, while he/she is using the 3DUI. In particular, we aim at measuring and processing EEG and other biosignals (e.g., pulse, galvanic skin response, electromyogram) in real-time in order to estimate mental states such as interaction error potentials or workload/attention levels, among others. This will be used to finely identify how intuitive, easy-to-use and (ideally) enjoyable any given 3D UI is. More specifically, it will allow us to identify how, when and where the UI has flaws. Because the analysis will occur in real-time, we will potentially be able to modify the interface while the user is interacting. This should lead to a better understanding of 3D interaction. The work that will be achieved in this area could potentially also be useful for 2D interface design. However, since Potioc's main target is 3DUI, we will naturally focus the real-time cognitive evaluations on 3D contexts, with specific targets such as depth perception, or perception of 3D rotations.

This real-time cognitive analysis will be a third answer to reach the objectives of Potioc, which are to open 3D digital worlds to everyone by increasing the pleasure of use.

4. Application Domains

4.1. Application domains

Since our project aims at providing 3D digital worlds to all, including the general public, in order to stimulate understanding, learning, communication and creation, our scope of applications will naturally be the following one:

- **Culture and education:** We are convinced that a 3D digital world is a powerful media that may contribute to enhance understanding processes. For example, a museum would benefit from new 3D user interfaces allowing visitors to better understand complex content. Similarly, at school, this media has an extraordinary potential for enhancing learning. For example, a child being able to navigate in archaeological sites, or being able to manipulate by himself 3D molecules as described previously, will probably understand and learn things while having pleasure in interacting with the content.
- **Art:** We believe that 3D digital worlds may stimulate creativity, too. Our first investigations with music and drawings have shown that this media opens new possibilities for creation. The challenge here will be to design good interfaces that will allow artists to explore new dimensions. The user may be an experienced artist, or a three years old child who would express his creativity thought tools that go beyond papers and pens.
- **Healthcare:** People suffering from motor or cognitive impairments are one of the target populations of the Potioc project. Indeed, we believe that new interfaces that exploit 3D digital worlds may help people to overcome their disabilities. For example, someone with very reduced motor capabilities could benefit from BCI to explore a virtual museum, or a children having difficulties for concentrating may benefit from new 3D interactive systems.
- **Entertainment:** The objective of Potioc is to open 3D digital worlds to everyone by designing innovative interfaces driven by enjoyment. Consequently, the entertainment industry will be an obvious application domain where Potioc can contribute. This can be in the scope of videogames, entertainment parks, Web and TV of the future, applications for mobile devices, and so on.

Naturally, we will not necessarily address all these applications, and certainly not all at the same time. These areas just define the applicative scope of our work. As an example, much of our current work is targeted at artistic and entertainment applications, with VR-based musical performances, augmented paper-based drawing or BCI-based video games. We are also currently starting to conduct research on digital cities, in order to provide ordinary citizens suitable tools and UI to explore 3D content related to their city, such as 3D maps, information about population density or sound nuisance, among other. It should also be noted that our work might find applicative connexions outside these main application domains and benefit to a large range of academic and industrial areas, with which we could build relationships. For example, in the scope of medicine, new and easy to adopt user interfaces designed in Potioc could prove valuable for medical professionals as well, to better access and interact with biological 3D content (e.g., X-rays or MRI scans).

5. Software

5.1. OpenViBE

Participants: Fabien Lotte [local correspondant], Alison Cellard [engineer].

As part of our research work on BCI, we contribute to the development of the OpenViBE [4] software, which is an open source platform dedicated to the design, evaluation and use of BCI for real and virtual applications. OpenViBE development is leaded by Inria, and Potioc will be one of the Inria team contributing to its evolution. Moreover, Potioc is implied in an Inria ADT (Technological Development Action) project that has just started, an that is dedicated to the development of OpenViBE together with 3 other Inria teams (Hybrid, Athena, Cortex).

5.2. Drile

Participant: Florent Berthaut.

As part of the research on Virtual Reality for Musical Performance, notably the Drile system, various software are being developped and made available to the community. These software pieces are the following:

- Pure-Data external to access data from the Virtual Reality Peripheral Network : https://github.com/scrime/vrpd
- Drile: http://hitmuri.net/index.php/Research/Drile

6. New Results

6.1. Spatial augmented reality for physical drawing

Participants: Jérémy Laviole, Martin Hachet.

Spatial augmented reality (SAR) promises the integration of digital information in the real (physical) world through projection. We proposed different tools to improve speed or ease the drawing by projecting photos, virtual construction lines and interactive 3D scenes (published in the 3DUI symposium [16]). We explored the creation of tools which help to create drawings that are “difficult” to achieve for a human being, such as stereographic drawings (published in the 3DCHI CHI workshop [18]). Through these tools, we want to apply existing computer graphics techniques to enhance existing drawing tools, and to use it to teach how to draw. Furthermore, we proposed some insights for the creation of digital games and programs which can take full advantages of physical drawings (published in the UIST doctoral symposium [17]).

6.2. Brain-Computer Interfaces

Participants: Fabien Lotte, Florian Larrue, Martin Hachet.

As part of our research on Brain-Computer Interfaces (BCI), our contributions addressed two different levels: 1) the brain signal processing level, in order to design more efficient BCI systems and 2) the applications level, in order to propose and explore new BCI applications.

[4] http://openvibe.inria.fr

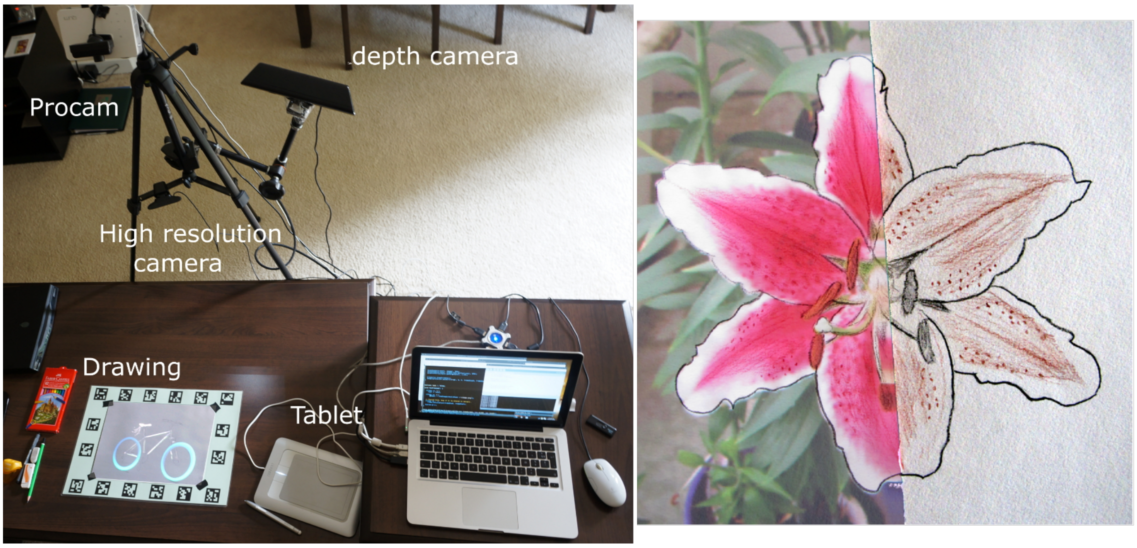

Figure 3. Left: Spatial augmented reality system for physical drawing. Right: Projection of a source image on overlay of an actual drawing, to teach drawing thanks to computer graphic tools [16].

At the signal processing level, we explored and designed new features to represent ElectroEncephaloGraphic (EEG) signals. In particular we explored multifractal cumulants and predictive complexity features (which we published in the Neurocomputing journal [5]), as well as waveform length features together with an optimal spatial filter that we designed for such features (which we published in the ICPR international conference [19]). All these features proved useful to classify EEG signals, and, more importantly, increased the classification performances of the system when combined together with the gold standard features, namely, band power features. Thus, this contributed to extending the repertoire of features available to BCI designers as well as increasing BCI performances. Nevertheless, our studies of BCI and educational research led us to the conclusion that current BCI feedback training approaches (which aimed at teaching people how to use a BCI and how to control their own brain activity), are most probably highly inappropriate and one of the major causes for the limited performances of current BCI - maybe more than signal processing methods. We therefore stressed the need for alternative feedback training approaches for BCI in a publication at the international BBCI workshop [20].

At the application level, we mostly focused on Virtual Reality (VR) related applications. Indeed, together with other groups in the field, we reviewed how BCI and VR could be combined in order to give rise to new applications and to improve BCI designs. This was published in a book chapter dedicated to BCI [22]. Similarly, with international colleagues, we reviewed and envisioned new applications of BCI outside the medical domain, and proposed guidelines to move towards these new applications. This notably includes VR and game applications, user-state monitoring, neuro-evaluation, training and education, cognitive improvement as well as safety and security. This was published in the IEEE Computer journal [8]. Finally, we proposed a new and innovative application of BCI: using it as a tool to study spatial cognition and transfer from VR to real environments. In particular, since BCI can be used to navigate a Virtual Environment (VE) without any motor activity, BCI can be used to assess how much motor activity is really needed to transfer spatial knowledge from a VE to a real one. This is what we did by comparing a BCI and a treadmill in order to teach users a path in a VE and then asking them to retrieve this path in the real world. Contrary to what was believed before, our results showed that motor activity is not necessary to learn a path in VR. We showed that what is really necessary is performing an action, but that this action does not have to be motor, and can be, for instance, cognitive (e.g., imagining hand movements), with a BCI. This was published in the VRST international conference [14].

Figure 4. A user navigating a virtual model of the city of Bordeaux with a BCI, in order to learn a specific path [14].

6.3. Understanding user gestures for touch screen-based 3D User Interfaces

Participants: Aurélie Cohé, Martin Hachet.

In the scope of the ANR project Instinct, we studied how users tend to interact with a touchscreen for interacting with 3D content. Our main contributions were to study user behaviors with a standard touchscreen on the one hand, and with a pressure sensitive touchscreen on the other hand.

Multi-touch interfaces have emerged with the widespread use of smartphones. Although a lot of people interact with 2D applications through touchscreens, interaction with 3D applications remains little explored. Most 3D object manipulation techniques have been created by designers who have generally put users aside from the design creation process. We conducted a user study to better understand how non-technical users tend to interact with a 3D object from touchscreen inputs. The experiment has been conducted while users were manipulating a 3D cube with three viewpoints for rotations, scaling and translations (RST). Sixteen users participated and 432 gestures were analyzed. To classify data, we introduce a taxonomy for 3D manipulation gestures with touchscreens. Then, we identify a set of strategies employed by users to perform the proposed cube transformations. Our findings suggest that each participant uses several strategies with a predominant one. Furthermore, we conducted a study to compare touchscreen and mouse interaction for 3D object manipulations. The results suggest that gestures are different according to the device, and touchscreens are preferred for the proposed tasks. Finally, we propose some guidelines to help designers in the creation of more user friendly tools. This work was published in the Graphics Interface (GI) conference [12] as well as in the Computers and Graphics journal [6].

Moreover, few works have focused on the relation between the manipulated data and the quantity of force applied with the fingers sliding on a touch sensor. In another work, we conducted two user studies to better understand how users manage to control pressure, and how they tend to use this input modality. A first set of experiments allows us to characterize pressure in relation to finger motions. Based on the results of this study, we designed a second set of experiments focusing on the completion of 3D manipulation tasks from 2D gestures. The results indicate that a strong relationship exists between the actions the participants intend to perform, and the quantity of force they apply for 3D object manipulations. This finding opens new promising perspectives to enhance user interfaces dedicated to force-based touch sensors.

All these works were published in the PhD thesis of Aurélie Cohé [4], which was defended on December 13th, 2012.

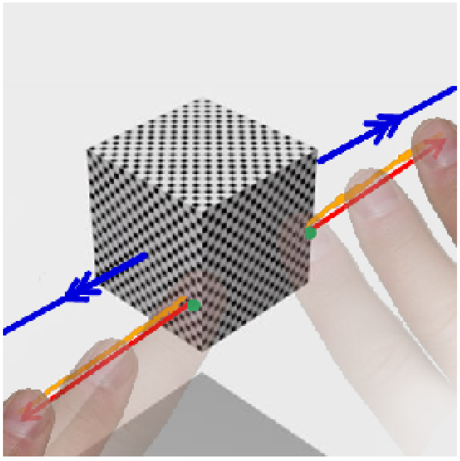

Figure 5. Analysis of users' gestures on touch screen to manipulate 3D content [6].

6.4. Virtual reality for Musical Performance

Participants: Florent Berthaut, Martin Hachet.

Immersive virtual environments open new perspectives for music interaction, notably for the visualization of sound processes and of musical structures, for the navigation in musical compositions, for the manipulation of sound parameters and for musical collaboration. Research conducted by Florent Berthaut and Martin Hachet, in collaboration with Myriam Desainte-Catherine from the SCRIME/LaBRI, explore these new possibilities.

Among the current projects, development of the Drile immersive virtual musical instrument was pursued in order to enable various scenographic setups that will be evaluated in the context of public performance. New perspectives for the Tunnels, 3D widgets for musical modulation (see Figure 6), were published as a Poster in the Proceedings of the Symposium on 3D User Interfaces (3DUI) [10]. Novel 3D selection techniques that take music interaction constraints into account are also being designed.

Another project was conducted with David Janin and Benjamin Martin from the LaBRI on new musical models that will be used to improve the hierarchical musical structures manipulated with Drile. It was published in the International Conference on Semantic Computing [11].

A collaboration was started with researchers of the Center for Computer Research on Music and Acoustics (CCRMA) of Stanford University. Florent Berthaut was invited for two months at CCRMA, where he worked with Luke Dahl and Chris Chafe on the implementation of musical collaboration modes in immersive virtual environments. A first result is the design of 3D musical collaboration widgets for Drile, which will be evaluated with musicians.

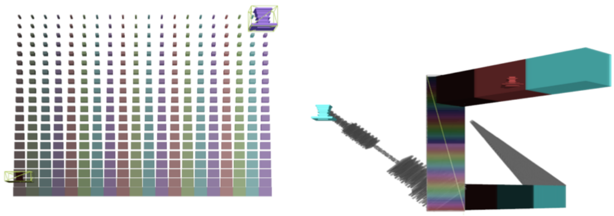

Figure 6. The Tunnels 3D widgets for musical modulation.

Another project was initiated with researchers of the Bristol Interaction and Graphics group of the University of Bristol. This project aims at improving the audience experience with Digital Musical Instruments (DMIs). These instruments are often confusing for spectators because of the variety of used components and because of the lack of physical continuity between musicians gestures and the resulting sound. A novel approach was implemented using a mixed-reality system in order to reveal the mechanisms of DMIs (see Figure 7). A description of this approach and of the first prototype will be submitted to the conference on New Interfaces for Musical Expression.

6.5. Gateway driving simulator

Participants: Florian Larrue, Pauline Davignon, Pierre-Alexandre Favier, Martin Hachet.

As part of the SIMCA FUI project, the POTIOC team focuses on the design and evaluation of a gateway driving simulator, to teach drivers how to drive an airport gateway in virtual reality, i.e., in a safe and cost-effective environment. Gateways are the means to transfer passengers between the airport and the plane, for departures and arrivals. We have developped 3 simulators with different immersion levels (small, medium and immersive simulators, see, e.g., Figure 8). For each immersion level, we developped protocols in order to evaluate the impact of 3D technologies such as stereoscopy and head tracking on users' performances and preferences. Experimentations and evaluations are currently in progress.

7. Partnerships and Cooperations

7.1. Regional Initiatives

- Potioc has strong relationships with Cap Sciences http://www.cap-sciences.net/
- Potioc has started a collaboration with La CUB (Communauté Urbaine de Bordeaux). Joint Master thesis on "visualization of strategic data in 3D cities"

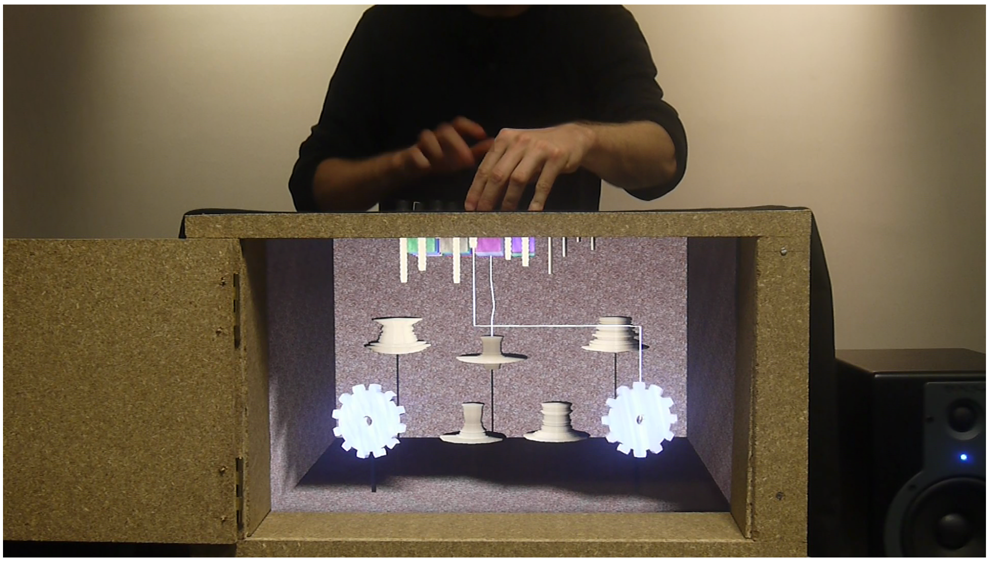

Figure 7. Rouages: a mixed-reality system that reveals the mechanisms of digital musical instruments to the audience.

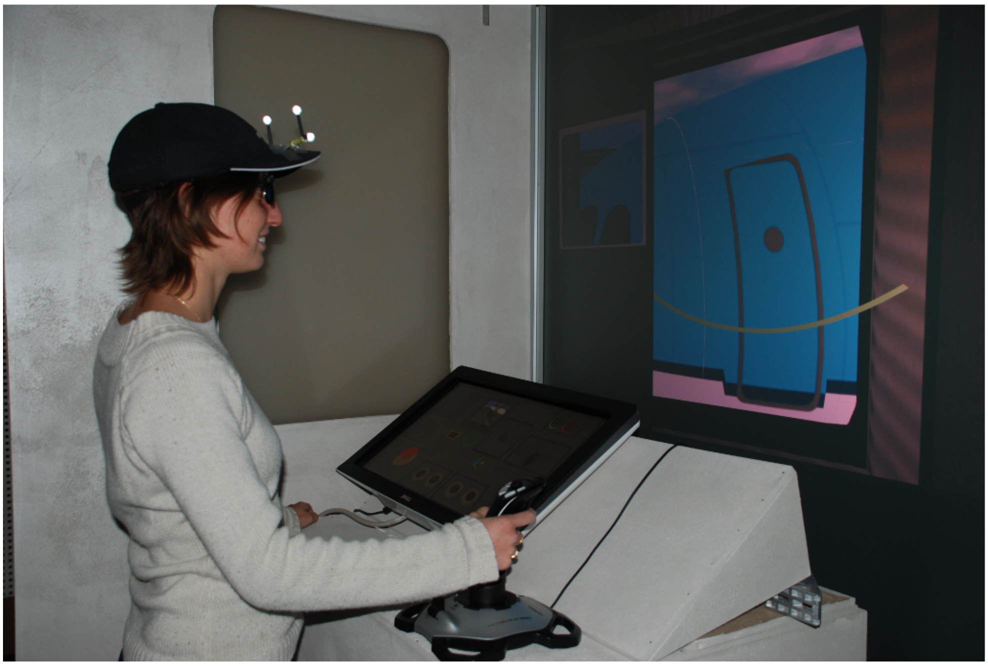

Figure 8. A user, equipped with head tracking and stereoscopic glasses, using the gateway driving simulator.

7.2. National Initiatives

ANR Project Instinct:

duration: 2009-2012

partners: MINT (Inria Lille), Immersion, Cap Sciences

website: http://anr-instinct.cap-sciences.net/

FUI SIMCA 2000:

duration: 2011-2013

partners: Oktal, ENAC (Ecole Nationale de l'Aviation Civile), Toulouse-Blagnac airport, Air France, CGx AERO in SYS

website: https://team.inria.fr/potioc/fr/collaborative-projects/simca/

PIA ville numérique "Villes transparentes":

duration: 2012-2014

partners: Pages Jaunes/Mappy, Vectuel/Virtuelcity

Inria ADT OpenViBE-NT:

duration: 2012-2014

partners: Inria teams Hybrid, Neurosys and Athena

website: http://openvibe.inria.fr

7.3. European Initiatives

LIRA Stress and Relaxation project:

Program: Inria - Philips - Fraunhofer partnership

Project acronym: LIRA

Project title: LIfe-style Research Association, Lifestyle Management: Stress and Relaxation

Coordinator: Frederic Alexandre

Other partners: Philips (Netherlands), Fraunhofer (Germany), Inria teams Hybrid and Mimetic

Abstract: The Stress and Relaxation project aims at offering services to a user, at home or at work, to help this user evaluate and control his level of stress

7.4. International Initiatives

7.4.1. International Partners

- Institute for Infocomm Research (I2R), Singapore - Wadsworth Center, Albany, USA and Kansas University, USA.
  Topic: Analysis of speech production and perception from ECoG signals
- BIG (Bristol Interaction Group), University of Bristol, UK.
  Topic: 3D User Interfaces and Musical Performance.

7.5. International Research Visitors

7.5.1. Visits to International Teams

- A. Cohé visited the BIG (Bristol Interaction and Graphics), in Bristol, UK, during 1 month

- F. Berthaut visited the Center for Computer Research on Music and Acoustics (CCRMA) of Stanford University, USA, during 2 months
- J. Laviole did a 3 month intership at Microsoft Research Redmond, USA

8. Dissemination

8.1. Scientific Animation

8.1.1. Reviewing

Potioc team members have been involved in the review of numerous submissions in conferences and journals. They include:

- **Conferences:** Sound and Music Computing Conference 2012 (F. Berthaut), CHI 2013 (J. Laviole, F. Lotte, J. Jankowski, A. Cohé), 3DUI 2013 (J. Laviole, F. Lotte, J. Jankowski), JVRC 2012 (A. Cohé), VRST 2012 (F. Larrue), BBCI workshop 2012 (F. Lotte), ECAI 2012 (F. Lotte), ICMI 2012 (F. Lotte), ICMI Grand Challenge on BCI 2012 (F. Lotte), PRNI 2012 (F. Lotte), NordiCHI 2012 (F. Lotte)
- **Journals:** Computer and graphics (M. Hachet), AJSE (M. Hachet), Biomedical Engineering Online (F. Lotte), Eurasip Journal on Advances in Signal Processing (F. Lotte), Frontiers in Neuroprosthethics (F. Lotte), IEEE Transactions on Biomedical Engineering (F. Lotte), IEEE Transactions on Computational Intelligence and Artificial Intelligence in Games (F. Lotte), IEEE Transactions on Neural Systems and Rehabilitation Engineering (F. Lotte), IEEE Transactions on Systems, Man and Cybernetics, Part A (F Lotte), International Journal of Neural Systems (F Lotte), Journal of Neural Engineering (F. Lotte), Journal of Neurosciences Methods (F. Lotte)

8.1.2. Program Committees Members

- IEEE VR 2013 (M. Hachet)
- European Conference on Artificial Intelligence 2012 (ECAI 2012) (F. Lotte)
- International Conference on Multimodal Interaction 2012 (ICMI 2012 – Area Chair) (F. Lotte)
- Grand challenge on BCI at ICMI 2012 (F. Lotte)
- International Workshop on Pattern Recognition in NeuroImaging 2012 (PRNI 2012) (F. lotte)

8.1.3. Other

- Guest Editor for IEEE Transactions on Computational Intelligence and Artificial Intelligence in Games, together with D. Coyle, J. Principe and A. Nijholt, for the special issue "Brain/Neuronal-Computer Games Interfaces and Interaction", 2012 (F Lotte)
- Organiser of a workshop on NeuroDesign with Architect Pierre Cutellic at the Advance in Architectural Geometry (AAG 2012) international conference (F Lotte)

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

Teaching at ENSEIRB engineering school:

Master: Martin Hachet, Virtual Reality, 15h, 3rd Year, ENSEIRB, France

Master: Florent Berthaut, Virtual Reality, 9h eqTD, M2, ENSEIRB, France

Master: Florent Berthaut, Music Interaction, 8h eqTD, M2, ENSEIRB, France

Master: Florent Berthaut, Human Computer Interation, 8h eqTD, M1, ENSEIRB, France

Master: Florent Berthaut Jérémy Laviole, 3D Music Instrument Project, 20h eqTD, M2, ENSEIRB, France

Teaching at University of Bordeaux 1:

Licence: Jérémy Laviole, Introduction to Computer Science, 25h Course + 17.3h practical work. L1, University of Bordeaux 1, France

Licence: Florent Berthaut, Initiation to Computer Science, 30h eqTD, L1, University of Bordeaux 1, France

Licence: Florent Berthaut, UNIX, 16h eqTD, L3, University of Bordeaux 1, France

Licence: Jérémy Frey, Réseau et projet de programmation 2, 30h eqTD, L3, University of Bordeaux 1, France

Licence: Jérémy Frey, C2i - certificat informatique et internet, 14h eqTD, L1, University of Bordeaux 1, France

Master: Jérémy Laviole, Research Project, 10h. M2, University of Bordeaux 1, France

Master: Florent Berthaut Jérémy Laviole, Virtual Reality, 24h eqTD, M2, University of Bordeaux 1, France

Master: Florent Berthaut, Object Oriented Programming, 30h eqTD, M1, University of Bordeaux 1, France

Master: Florent Berthaut, C++, 16h eqTD, M2, University of Bordeaux 1, France

Master: Florent Berthaut, Project Management, 30h eqTD, M1, University of Bordeaux 1, France

Teaching at University of Bordeaux 2:

Master: Martin Hachet, Fabien Lotte, Virtual Reality and 3D Interaction, 8h each, Master 2 Cognitive Sciences, University of Bordeaux 2, France

Master: Florian Larrue, Réalité Virtuelle, Interfaces et Navigation, 5h, Master Recherche Sciences Cognitives, University of Bordeaux 2, France

Various other teaching activities:

Ecole de Podologie: Florian Larrue, Introduction à la sécurité et à l'Informatique, 18h, Ecole de Podologie Bordeaux, France.

Ecole de Podologie: Florian Larrue, Formation Word, Excel, Powerpoint, 30h, Ecole de Podologie Bordeaux, France

Master: Fabien Lotte, Virtual Reality and Brain-Computer Interfaces, 6h eqTD, 2nd and 3rd year, ENSSAT Lannion, France

Architecture School (all years): Fabien Lotte, Brain-Computer Interfaces and Neurodesign, 16h, ENSAPM Paris, France

Master/Doctorat: Fabien Lotte, Spatial filtering techniques for practical Brain-Computer Interfaces, 2h, Berlin BCI neurotechnology summer school, Berlin, Germany

8.2.2. Supervision

PhD: Aurélie Cohé, "Manipulating 3D content on Touch Screens", Université de Bordeaux, defended December 13th 2012, supervised by Martin Hachet and Pascal Guitton

PhD in progress: Jérémy Frey, "Using Passive Brain-Computer Interfaces to assess and design 3D User Interfaces", Université de Bordeaux, started October 1st 2012, supervised by Fabien Lotte and Martin Hachet

PhD in progress: Jérémy Laviole, "Projection Mapping for Physical Drawing", Université de Bordeaux, started October 1st 2010, supervised by Martin Hachet

PhD in progress: Renaud Gervais, "Desktop-based stereoscopy", Inria - Université de Bordeaux, started October 1st 2012, supervised by Martin Hachet

8.2.3. Juries

PhD juries:

- Laurent George, Insa de Rennes, December 8, 2012 (M. Hachet - examinateur)
- Francisco Javier Velasco Alvarez, Malaga University, Spain, November 23, 2012 (F. Lotte)

8.3. Popularization

- Creatives Tuesday, Bordeaux, 27th November, "New 3D User Interfaces for the city" (M. Hachet)
- Les signaux du numériques, Talence, 5th March, Demo PapARt (M. Hachet, P. Davignon)
- Participation to the exhibition "Lascaux" in Cap Sciences (PapARt, Toucheo), (M. Hachet, J. Laviole)
- Participation to the Aquitec student job fair, doing demonstrations and talking about jobs in computer science research (P. Davignon, J. Laviole)
- Interview for the journal “Sciences et Vie Junior”, about Brain-Computer Interfaces (F. Lotte)
- Talk given at the science festival in Goteborg, Sweden, entitled “Playing with the brain: Using ‘Brain-Computer Interface’ to control video games with mental activity” (F. Lotte)
- Interview for a TPE for high schools student about “Touch-based interactive technologies” (J. Frey)
- Care of an high school student (classe de sconde) visiting the Potioc group for a week
- Care of a junior high school student (classe de troisième) visiting the Potioc group for a week

9. Bibliography

Major publications by the team in recent years

[1] A. Cohé, M. Hachet. *Beyond the mouse: Understanding user gestures for manipulating 3D objects from touchscreen inputs*, in "Computers and Graphics", December 2012 [*DOI :* 10.1016/j.cag.2012.09.004], http://hal.inria.fr/hal-00737900.

[2] F. Larrue, H. Sauzeon, L. Aguilova, F. Lotte, M. Hachet, B. Nkaoua. *Brain Computer Interface Vs Walking Interface in VR: The Impact of Motor Activity on Spatial Transfer*, in "Virtual Reality Software and Technologies (VRST 2012)", 2012, http://hal.inria.fr/hal-00743522.

[3] J. Laviole, M. Hachet. *Spatial augmented reality to enhance physical artistic creation.*, in "25th ACM Symposium on User Interface Software and Technology (UIST)", Cambridge, MA, United States, October 2012, http://hal.inria.fr/hal-00724116.

Publications of the year

Doctoral Dissertations and Habilitation Theses

[4] A. Cohé. *Manipulation de contenu 3D sur des surfaces tactiles*, University of Bordeaux, December 2012.

Articles in International Peer-Reviewed Journals

[5] N. Brodu, F. Lotte, A. Lécuyer. *Exploring Two Novel Features for EEG-based Brain-Computer Interfaces: Multifractal Cumulants and Predictive Complexity*, in "Neurocomputing", 2012, vol. 79, n^{o} 1, p. 87-94, http://hal.inria.fr/inria-00632546.

[6] A. Cohé, M. Hachet. *Beyond the mouse: Understanding user gestures for manipulating 3D objects from touchscreen inputs*, in "Computers and Graphics", December 2012 [*DOI :* 10.1016/j.cag.2012.09.004], http://hal.inria.fr/hal-00737900.

[7] F. Lotte. *Les Interfaces Cerveau-Ordinateur: Conception et Utilisation en Réalité Virtuelle*, in "Revue Technique et Science Informatiques", 2012, vol. 31, n^{o} 3, p. 289-310, http://hal.inria.fr/hal-00659822.

[8] J. B. VAN ERP, F. LOTTE, M. TANGERMANN. *Brain-Computer Interfaces: Beyond Medical Applications*, in "Computer -IEEE Computer Society-", April 2012, vol. 45, n^{o} 4, p. 26-34 [*DOI :* 10.1109/MC.2012.107], http://hal.inria.fr/hal-00688344.

International Conferences with Proceedings

[9] J. ACEITUNO, J. CASTET, M. DESAINTE-CATHERINE, M. HACHET. *Improvised interfaces for real-time musical applications*, in "Tangible, embedded and embodied interaction (TEI)", Kingston, Canada, February 2012, http://hal.inria.fr/hal-00670576.

[10] F. BERTHAUT. *Poster: Beyond the Tunnels: Advanced 3D graphical modulation*, in "Proceedings of the Symposium on 3D User Interfaces (3DUI'12)", 2012, p. 139-140.

[11] F. BERTHAUT, D. JANIN, B. MARTIN. *Advanced synchronization of audio or symbolic musical patterns*, in "Sixth IEEE International Conference on Semantic Computing", 2012, p. 202-209.

[12] A. COHÉ, M. HACHET. *Understanding user gestures for manipulating 3D objects from touchscreen inputs*, in "Graphics Interface", Toronto, Canada, ACM, May 2012, p. 157-164, http://hal.inria.fr/hal-00680561.

[13] B. DE ARAUJO, G. CASIEZ, J. JORGE, M. HACHET. *Modeling On and Above a Stereoscopic Multitouch Display*, in "3DCHI - The 3rd Dimension of CHI", Austin, United States, May 2012, p. 79-86, http://hal.inria.fr/hal-00670565.

[14] F. LARRUE, H. SAUZEON, L. AGUILOVA, F. LOTTE, M. HACHET, B. NKAOUA. *Brain Computer Interface Vs Walking Interface in VR: The Impact of Motor Activity on Spatial Transfer*, in "Virtual Reality Software and Technologies (VRST 2012)", 2012, http://hal.inria.fr/hal-00743522.

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[16] J. LAVIOLE, M. HACHET. *PapARt : interactive 3D graphics and multi-touch augmented paper for artistic creation*, in "3DUI - IEEE Virtual Reality Conference", Orange County, United States, IEEE, March 2012, http://hal.inria.fr/hal-00662632.

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[18] J. LAVIOLE, F. LOTTE, M. HACHET. *Digitally assisted stereo drawing*, in "The 3rd Dimension of CHI (3DCHI) - Workshop at CHI 2012", Austin, United States, May 2012, http://hal.inria.fr/hal-00671361.

[19] F. LOTTE. *A new feature and associated optimal spatial filter for EEG signal classification: Waveform Length*, in "International Conference on Pattern Recognition (ICPR)", Tsukuba, Japan, 2012, http://hal.inria.fr/hal-00717617.

[20] F. LOTTE. *On the need for alternative feedback training approaches for BCI*, in "BBCI Workshop 2012", Berlin, Germany, 2012, http://hal.inria.fr/hal-00766703.

National Conferences with Proceeding

[21] F. DUFOUR, M. HACHET, G. GIRAUDON, P. GUITTON, T. VIÉVILLE. *Comment utiliser le 3.0 pour que notre MINF soit ubiquitaire, participatif et attractif ?*, in "Vers un musée de l'informatique et de la société numérique en France.", Paris, France, I. ASTIC, P.-E. MOUNIER-KUHN, P. PARADINAS (editors), CNAM et ACONIT, November 2012, http://hal.inria.fr/hal-00756476.

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[22] F. LOTTE, J. FALLER, C. GUGER, Y. RENARD, G. PFURTSCHELLER, A. LÉCUYER, R. LEEB. *Combining BCI with Virtual Reality: Towards New Applications and Improved BCI*, in "Towards Practical Brain-Computer Interfaces:", B. Z. ALLISON, S. DUNNE, R. LEEB, J. D. R. MILLÁN, A. NIJHOLT (editors), Springer, 2013, http://hal.inria.fr/hal-00735932.