Visualization, Interaction and Simulation Lab

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***Abstract*—The Visualization, Interaction, and Simulation Laboratory (VISLab) at UFRGS is majorly concerned with data visualization and human-computer interaction research. Research on data visualization focuses on the development of information visualization techniques and their application to different domains. Studies on interaction emphasize non-conventional, 3D interaction and haptics in the context of virtual (VR) and augmented reality (AR) applications. We integrate these two areas into immersive analytics research and develop data visualization and novel interaction techniques based on VR and AR technologies. The main goal of our projects is to enhance the human with computers, extending the perception capabilities and improving the human power of action in a natural way. In this paper, we present our research focus and strategy to move towards that goal. We also briefly describe and illustrate some recent works developed in the lab.**

I. INTRODUCTION: RESEARCH FOCUS AND STRATEGY

The Visualization, Interaction and Simulation Laboratory (VISLab) at UFRGS is part of the Computer Graphics, Image Processing, and Interaction research group, which started its activities in 1978, developing projects mainly on rendering, animation, and scientific visualization. Over the years, new researchers joined the group and the group's interests targeted new areas, such as image acquisition and analysis, virtual reality, non-conventional interaction, and information visualization.

In a quest for mechanisms to enhance the human with computers, we have been investigating new technologies and techniques that may contribute to extend human perception and enlarging our power of action. This strategy is coupled with the concepts of calm and natural interfaces, where computers become ubiquitous, and users live in a fully connected world, being constantly updated through their senses and acting precisely and naturally. Such natural interfaces have significant importance when we consider that most human activities involve decisions based on the large and complex volume of data that surrounds us.

To accomplish our goals, we are conducting research on data visualization and human-computer interaction (HCI) in a broad sense, including visual analytics, non-conventional and 3D interaction, haptics techniques, and the use of mobile and wearable devices to allow the implementation of these concepts everywhere. Presently, our research on data visualization and HCI is heavily influenced by virtual and augmented reality (VR/AR) setups, implying studies on immersive analytics and situated visualization. Results contribute to real applications (e.g., health care and data journalism) and are tested with final users whenever possible.

While our data visualization research focuses on giving users simple but powerful and interactive graphical representations to support their tasks or interests, our HCI research focus is built on the assumption that human-computer communication should go beyond the eyes to include the touch and the auditory systems. This implies using the most out of the computational resources available to enhance human activity with all helpful sensory (not only visual) information in harmony with our living environment while bearing in mind the human tasks the systems are entitled to support. Our goals touch a number of computational and human aspects covered by the projects in the different research lines conducted by the VISLab members.

II. RECENT RESULTS

In this section we provide an overview of some results that illustrate our research on visualization and HCI. The complete list of projects can be found at the lab's web page.

Information visualization. In the last decade, we have developed several visualization techniques aiming at supporting visual analysis of co-authorship networks and roll call data. We investigated how to represent queries in magnets that change the network force-based layout, so the nodes answering the query become more visible [1]. Later, we developed techniques for exploring multivariate networks, so a user could inspect attributes of relationships [2], [3] and clusters [4], all of them integrated within a multiple coordinated views system (MGExplorer) [5]. Roll call data allows us to study the behavior of the Brazilian deputies, among other facts. A previous work [6] has been extended [7] and integrated using the MGExplorer approach providing several visualizations that include infographics, scatterplots, timeline plot, among others (Fig. 1).

Over the last 3 years, we worked in partnership with an epidemiological research team. They are conducting a randomized clinical trial to accompany women with gestational diabetes and have hundreds of questionnaires with data from each phase of the study. We developed an information-rich, visualization-based interface to allow monitoring the trial and perform some preliminary analysis [8] (Fig. 2).

HCI and 3D Interaction. The information visualization techniques described above are supported by the conventional

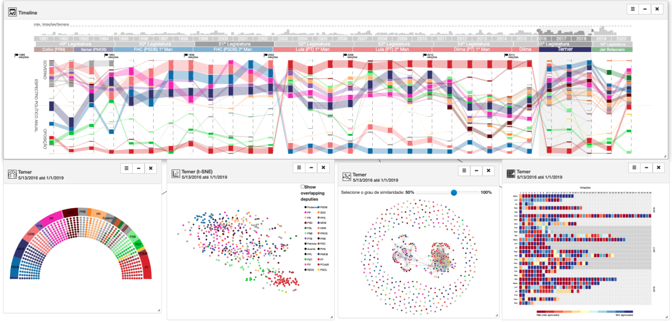

Fig. 1. Multiple views showing data obtained from the Brazilian Chamber of Deputies: timeline of parties behavior, chamber composition, political spectra, voting similarity graph, and map of roll calls for the selected period.

Fig. 2. Participants' Information Analysis interface, showing PCA results for a group of 91 participants. On the left side of the view a menu is available for filtering purposes, selecting the variables to be considered for building the scatterplot, viewing results and more. The right side of the view shows graphs of temporal variables on demand.

WIMP approach. However, we have been experimenting with several 3D interaction approaches, based on simple devices as smartphones, VR controllers, and haptic devices, which allows us to investigate the quality of such approaches for interacting with data and objects in large displays, virtual and augmented reality environments.

The use of mobile devices for 3D selection and manipulation presents two advantages: they are equipped with a rich set of sensors and fit greatly as pointing devices; almost everyone has a smartphone and carries it always and everywhere like an extension of their body.

We have successfully applied smartphone-based 3D interaction techniques for collaborative manipulation of virtual objects in VR and AR. Such novel paradigm for 3D manipulation supports smooth and intuitive collaborative actions. The approach coordinates and combines the multiple users rotations, translations and scales, as well as the camera control [9] (see Fig. 3). It has been proved advantageous for sharing the interaction complexity among many users. When applied in AR [10] this approach combines touch gestures and device movements for fast and precise control of 7-DOF transformations. Moreover, the interface creates a shared medium where several users can interact through their point-of-view and simultaneously manipulate 3D virtual augmentations.

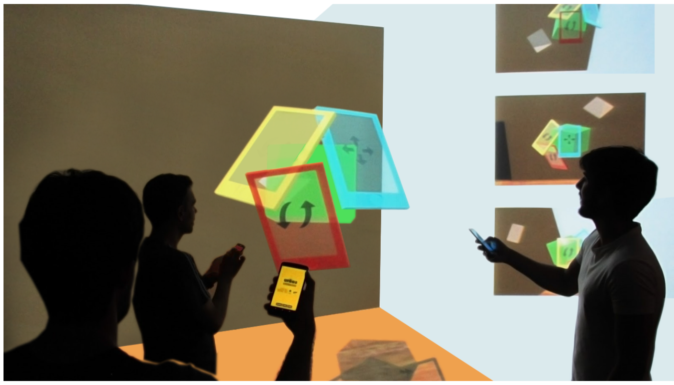

Fig. 3. Three users simultaneously driving the object through the virtual environment. The colored rectangles indicate the position and orientation of each user in the VE. The three windows at the right-side show the three personal views.

Haptic Interaction. Touch and force feedback are known to increase immersion and to enrich the sensorial experience in VR. But tactile signals can also be used to communicate ad hoc information in several human-to-human and human-computer scenarios.

We explored the actuator density and precision in vibrotactile displays and the acuity for vibration of the head's skin when using such devices [11], [12]. We have also designed and assessed haptic guidance techniques for 3D environments. We designed and assessed a vibrotactile HMD to render the position of objects in a 3D space around the user by varying both stimulus loci around the head and vibration frequency. This combination of stimuli convey respectively direction parallel to the ground and elevation [13].

More recently, we have been investigating the potential uses of other haptic devices like the EXOS Wrist DK2 [14], which is wearable and ungrounded, but still provides rotational stimuli around the wrist. Such stimuli, when combined with the visual information in a virtual environment, can potentially convey a suitable model for balance stimulation and weight perception.

Immersive Analytics. Current immersive technologies, which combine stereoscopic displays and natural interaction, are being progressively used for information visualization and data analyses. This has been called immersive analytics.

We have investigated the use of an HMD-based environment for the exploration of multidimensional data, represented in 3D scatterplots as a result of dimensionality reduction. Instead of the traditional interaction we implemented and evaluated an alternative data exploration metaphor where the user remains seated and viewpoint change is only realisable through physical movements. All manipulation is done directly by natural mid-air gestures, with the data being rendered at arm's reach. The virtual reproduction of the analyst's desk aims to increase immersion and enable tangible interaction with

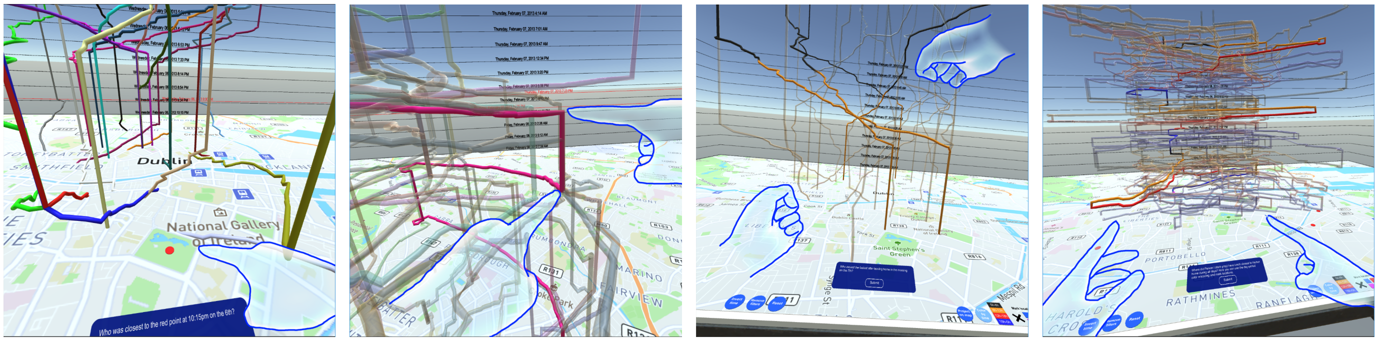

Fig. 4. Different tasks being performed in the Immersive condition with Dense data: comparisons of instant distance (left), stop durations (center left), movement speeds (center right) and event locations (right). Blue hand contours added for clarity.

controls and two dimensional associated information [15]–[17]. The $VirtualDesk$ approach has been used to evaluate an immersive space-time cube geovisualization for exploring trajectory data [18] (Fig. 4).

We are also studying the use of multiple coordinated 3D visualizations in immersive analytics environments. Recently, we proposed a new approach based on a 3D-WIMP-like concept, i.e., virtual cubes that we call $Spaces$ [19]. They encapsulate views (Fig. 5), and the user can freely control them in the virtual environment via $macro$ mode interaction. Operations like "cloning" and "coordinated interactions" provide a way for performing composed tasks, and the user can interact with the data inside the views via $micro$ mode interaction.

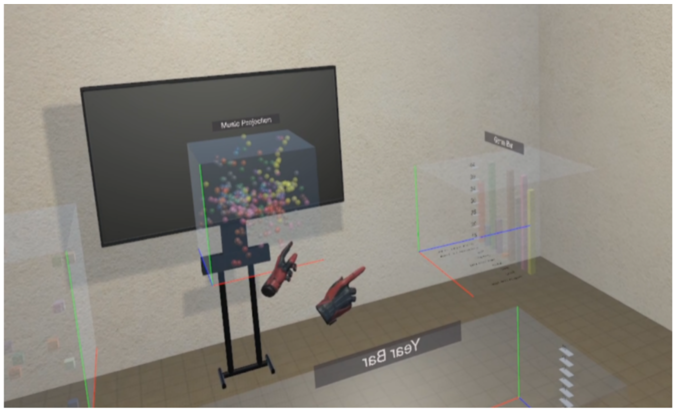

Fig. 5. The $Spaces$ approach provide multiple coordinated 3D views for supporting immersive analytics applications.

Situated Visualization. When using augmented reality devices, such as the HoloLens, we refer to such applications as situated visualization or situated analytics. We have also investigated the potential benefits of situated visualization in proof-of-concept applications. For example, an augmented reality user interface was developed to provide information for users to define the most convenient location to sit down in a conference room. This accounts for different sets of arbitrary demands by projecting 3D information directly atop the seats. Qualitative and quantitative data collected from a user study indicated that the augmented reality solution is promising in some senses and may help users to make better decisions [20]. Previously, in another work, we used virtual holograms placed on a terrain to guide user navigation instead of the usual heads-up display approach where the augmentations follow the line of sight [21]. More recently, we conducted a study with electromagnetic compatibility (EMC) data, where a user of AR glasses visualize, in a situated fashion, the EM fields around the physical devices that generate them. Situated interaction allows performing data readings accurately and efficiently.

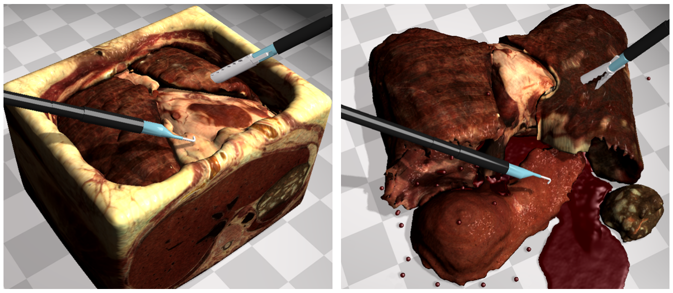

Fig. 6. Visual results from a fully dynamic cutting simulation with multiple materials. Thorax organs and other anatomical structures are shown. Nearly 10,000 particles and 30,000 constraints were simulated at haptic framerates.

Realistic Simulators. A great motivator for research in VR in the lab is surgery simulation. We have first worked on techniques for modeling organ shapes, joint motion and tissue deformation. Then, we explored collision detection and instrument-tissue interaction, and put that all together in a software framework based on game engines [22]. Currently, the main challenges reside on: creating customized patient models for surgery planning, improving physics-based behavior to simulate real tissue, and proposing new interaction techniques to manipulate medical data.

We have come up with a novel method that uses position-based dynamics for mesh-free cutting simulation. Our solutions include a method to efficiently render force feedback while cutting, an efficient heat diffusion model to simulate electrocautery, and a novel adaptive skinning scheme based on oriented particles [23] (see Fig. 6).

We also proposed the analysis of videolaparoscopy data to compute the Bidirectional Reflectance Distribution Function (BRDF) of living organs as an input to physically based rendering algorithms, and applied this technique in a case study around the liver with patient-specific rendering under global illumination [24].

Simulating the modeling of virtual dynamic objects in immersive VR is another challenging research topic. We have developed a new physics-inspired sketching technique built on the top of position-based dynamics to enrich the 3D drawings with dynamic behaviors. A particle-based method allows interacting in real time with a wide range of materials including fluids, rigid bodies, soft bodies and cloths [25].

III. FINAL COMMENTS

VISLab emerged from the integration of researchers with different expertise, which allows us to investigate (1) 2D information visualization techniques, either web-based or desktop-based, or in large displays, where interaction can be based on smartphones or whole-body movements capture; (2) immersive analytics techniques following different interaction approaches (e.g., $VirtualDesk$ or $Spaces$); and (3) augmented reality approaches for situated visualization, situated analytics or medical applications.

Due to these characteristics, VISLab welcomes students with varied backgrounds but with strong evidence of a research-oriented profile and also seeks collaboration with other groups to broaden research opportunities.

ACKNOWLEDGMENTS

The authors thank all the students involved in the past and on-going VR projects. Our research has been mainly supported by CNPq, CAPES (Finance Code 001), and FAPERGS. We also acknowledge the financial support from companies in different projects over the years (e.g., AESSul, Simedis AG, Microsoft, and Petrobras).

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