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IMMERSIVE DATA EXPLORATION AND ANALYSIS

ADRIEN FONNET

LS2N UMR6004 CNRS UNIVERSITY OF NANTES

ADRIEN.FONNET@UNIV-NANTES.FR

FLORIAN MELKI

LS2N UMR6004 CNRS UNIVERSITY OF NANTES

FLORIAN.MELKI@UNIV-NANTES.FR

YANNICK PRIÉ

LS2N UMR6004 CNRS UNIVERSITY OF NANTES

YANNICK.PRIE@UNIV-NANTES.FR

FABIEN PICAROUGNE

LS2N UMR6004 CNRS UNIVERSITY OF NANTES

FABIEN.PICAROUGNE@UNIV-NANTES.FR

GREGOIRE CLIQUET

READI DESIGN LAB – L'ECOLE DE DESIGN

G.CLIQUET@LECOLEDEDESIGN.COM

ABSTRACT

This paper belongs to the emerging immersive analytics research field. It presents a system for exploratory analysis of multi-dimensional data focusing on providing freedom of locomotion while remaining comfortable for long user session. The solution allows to investigate temporal traces through a 3D scatterplot using a cylindrical coordinate system. Users are free to move inside the tracked area either standing up or seated in a mobile chair. A limited user study (n=6) has been conducted to investigate if the designed solution was deemed appropriate for mobility and user comfort.

INTRODUCTION

Understanding and exploring multi-dimensional datasets is a critical process for any decision maker. Immersive analytics is an emerging research field aiming at providing supportive tool for data analysis and decision making through the use of immersive environment (Chandler 2015). Building upon the initial reflexion proposed in (Cliquet 2017) for HMD based immersive analytics, this work describes an exploratory system focusing on navigation, i.e. keeping the freedom of

room-scale movement while accounting for long-session.

RELATED WORK

Even though immersive analytics terminology has only been defined in 2015, using immersive environment for multi-dimensional data analysis and exploration has been investigated since 1996 (Symanzik 1996). Symanzik et al. used a CAVE to display 3D scatterplot, encoding additional attributes through color and shape, followed by (Ammoura2001, Nagel2001, Nagel2003, Nagel2008). Other hardwares have also been exploited, such as augmented reality through fiducial marker (Meiguins 2006) or 3D stereo with hand-tracking (Azzag 2006).

Our system focuses on the use of virtual reality head mounted display (HMD) to visualize multidimensional data like the Wizard solution (Datey 2002), or the works of Donalek et al. (Donalek 2014) and Filho et al. (Filho 2017). However, those solutions are either stand-up or desk only while we combine in our system both modalities. We use a tracked mobile chair, to allow users get both the comfort of being seated for long session and the freedom of free standing movement in the tracked space. Moreover, we use the chair's tablet as a support for menu selection to give haptic feedback through a tangible surface. Tangible surfaces have been used in immersive analytics serving other purposes such as a reference map for augmented reality visualization (Franz 2017), or as touch table hardware (Butscher 2018).

IDEA IMMERSIVE ANALYTICS SYSTEM

Our immersive analytics solution has been developed with Unity3D for HTC Vive HMD rendering display and HTC controllers as the main input for interaction.

SYSTEM PURPOSES

Our target activity is exploratory data analysis, where users are looking for insights within trace data without any precise hypothesis to test. The trace format we use in our system is composed of event. An event has generic attributes such as event type, date, actor (e.g. who does the action depicted in the event), as well as several type specific attributes.

VISUAL MAPPING

Each tuple of the dataset is represented by a sphere. This shape's choice limits occlusion at the cost of more computer processing (Ammoura 2001). A cylindrical coordinate system is used to place data points based on their generic attributes, see fig.1. Vertical axis represents users, horizontal curved axis time, and depth event types. Since additional data points specific attributes depend on the event type, using another general visual mapping would not be relevant, so readability has been improved by color coding event type information. User sessions appear quite naturally in this representation as alignments of sphere.

Aggregation is also used to limit occlusion, by grouping data points of the same user and same event type which are temporally close to each other. The resulting object, is a semi-transparent sphere that contains the data points spheres scaled down. This solution seems adequate to aggregate up to 10 data points.

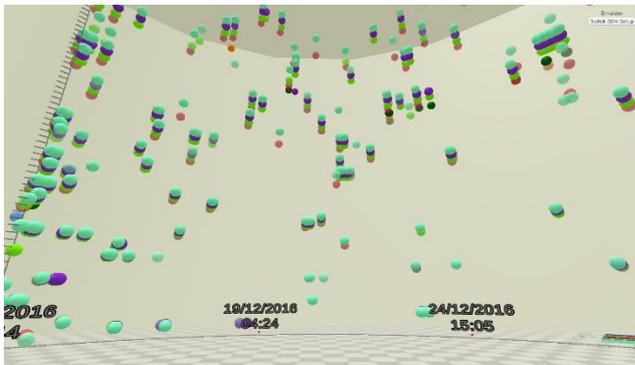


Figure 1: Overview of the virtual representation, each sphere representing a data point

INTERACTIONS MODALITIES

All elements for interaction have been put in the user vicinity and represents its workstation (see fig.2). A virtual disk represents the limit of the tracked physical space. A mobile chair, equipped with a tablet, tracked via Vive tracker (see fig.3) is modeled and positioned on top of the disk. Both Vive controllers are used, one dedicated for movement while the second is for data and menu interaction. A virtual trashcan and plank, positioned on both side of the chair, complete the setup.

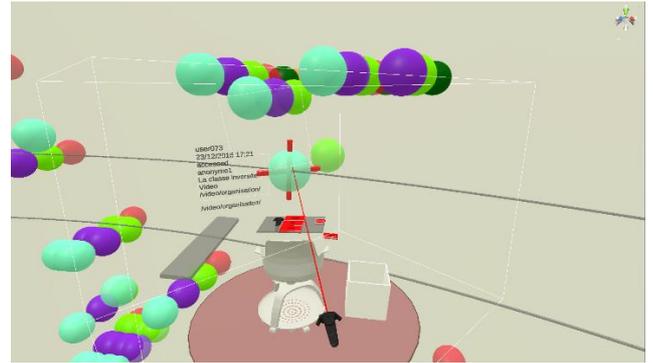


Figure 2: The workstation inside the virtual environment. The mobile chair and the tablet are modeled and tracked via Vive tracker. The virtual plank on the left is used to gather selection cube, while the trashcan on the right is used to discard cloned data point or selection cube. The disk represents the available physical area where the user can move while in the chair or standing up. "Flying" movement and teleportation move the whole workstation.



Figure 3: The mobile chair setup with a user exploring the dataset in seated position.

Up to 4 movements modalities are available for navigation. The first is physical displacement while standing up using the HTC Vive head-tracking. Second is the ability to physically move on the platform while seated, rolling the mobile chair over the disk. Third, the user can "fly" the workstation in the direction of the left controller combined with the trackpad input. Fourth, the user can teleport the workstation, by selecting direction and distance of teleportation, the point of arrival being visualized by a semi-transparent duplication of the disk + chair. Switching from flying to teleport is done via the left trigger. And last, pushing left grip button teleports the workstation back to a central position for the user to have the full data visualization in its field of view.

The user can point at a data point with a raycast from his right controller to access its full details. A window with all information appears next to the data if the

sphere is closed to the user and close to the user otherwise to optimize readability of the text. The same window can be triggered by putting the right controller in contact with a data point. Upon trigger press, a selected data point can also be duplicated and kept next to the workstation.

A menu is displayed on top of the chair's tablet to choose parameters for a data selection based on event type or user ID, multi-selection is available. Upon confirmation a virtual cube is generated in front of the user at arm's length. with the selection information written on it. This "selection cube" materializes the selection. Grabbing the cube with the right controller applies a highlight, i.e. a glowing effect on the selected data points. The cube can also be released on the top of the virtual plank to filter out all the data points that are not selected. Multiple selection cubes can be chained on the plank keeping visible only the data points at the intersection of the selection cubes. To undo a filter, the user can simply remove a cube from the virtual plank. A temporal zoom on the time axis is also available: the user can select two markers on the curved horizontal axis using the raycast. These markers are then used to change the visualization according to the new time interval.

Last, the virtual trashcan is used to destroy any unwanted object after use by placing them in contact with it, whether it is cloned data point or a selection cube.

USER STUDY

This section describes a limited user study conducted to draw some early conclusions. The focus was on qualitative aspects of the design, aiming to get user insights on visualization, interaction and comfort of use.

DATASET DESCRIPTION

The dataset explored contains traces extracted from the coconotes platform (<https://coconotes.comin-ocw.org/>) which is a e-learning video platform allowing user to annotate video at specific timestamp. Traces have been monitored over 5 months, from September 2016 to January 2017, and results of over 200 000 actions from 200 users. Only 17 users were used for the visualization resulting in only 5000 data points to render ensuring acceptable framerate in our preliminary prototype. Each tuple contains a user ID, a timestamp and an event type. Additional attributes depend on the event type, e.g. play or pause events will have specific attributes such as the name of the video.

EXPERIMENT

A participant's session lasted one hour. The following procedure was used: first a demographic questionnaire, then the presentation of the dataset and the visualization, and some training on interactions. Once we had the confirmation that the participant was comfortable with the system the main study started with

a set of tasks. A post questionnaire and an interview wrapped-up the session.

The study had two phases. In the first phase participants had to perform basic search tasks, e.g. find a video name knowing the time it was played and a user ID or determine a trend by answering questions such as "what behaviour may you observe after the completion of video reading?". In the second phase they could explore the system as they pleased, discovering new information about the dataset.

The post-questionnaire contained 4 affirmations on movement modalities, data visualization and interactions, comfort of use, and overall experience, the user had to evaluate with 7 points Likert scales.

Six male subjects from the computer science section of the University of Nantes participated to the study (mean age 20.8 ranging from 20 to 23). They had good experience in video game but few in virtual reality and data analysis. The experiment was run on a computer equipped with a CPU Intel Xeon ES-1630 v4 (3.70GHz), 16 Gb of RAM and a Nvidia GTX 1060 graphics card.

RESULTS

Movement modalities scored an average of 5 [0.58], main complaint was the slow velocity of the flying movement. However, scaling the speed up could result in increased cyber-sickness so complementary solution such as tunnelling effect should be added. The linear movement could also be replaced by dashing step.

Regarding data visualization and interactions, with a mean of 5 [1.15], the feedbacks was positive towards the cube selection object and trash can metaphor, improving the level of engagement. The details on demand feature was however unanimously disregarded due to the necessity of keeping the raycast over the point of interest, both tiring and frustrating gesture if the data is far away. Using the duplication of data point alleviated the problem during the study though this was not the intended goal of this feature.

Comfort of use was rated with a 5.33 [0.47] average and no cyber sickness was mentioned by users. Moreover, they appreciated the possibility to remain seated for analysis while having the freedom of moving when required. A full session only lasted around 30 minutes in the virtual world, so further study will be required to see if the system remains comfortable for longer period of time. It nevertheless shows encouraging results.

Last, the overall experience was rated with a mean of 5.66 [0.47], even though this can mostly be accounted for the "wow effect" of the first virtual reality and visual analytics experience based on the discussion with the subject.

CONCLUSION

This paper presented an immersive analytics system for multi-dimensional data analysis. The main contribution

is the navigation solution that provides the user with the comfort of using a seated position in front of a desk while retaining the freedom of using full physical movement while being immersed. The user feedback we obtained from a limited user study confirmed the benefits of our mobile chair solution. Future work will improve the data analysis component.

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