Selection of Large-Scale 3D Point Cloud Data Using Gesture Recognition

Robin Burgess, António J. Falcão, Tiago Fernandes, Rita A. Ribeiro, Miguel Gomes, Alberto Krone-Martins, André De Almeida

HAL Id: hal-01343482
https://inria.hal.science/hal-01343482

Submitted on 8 Jul 2016

Selection of Large-Scale 3D Point Cloud Data using Gesture Recognition

Robin Burgess, António J. Falcão, Tiago Fernandes, Rita A. Ribeiro, Miguel Gomes, Alberto Krone-Martins, André Moitinho de Almeida

UNINOVA / CTS, Campus FCT/UNL, Monte da Caparica, 2829-516 Caparica, Portugal
{rb, tmf}@ca3-uninova.org, {rar, ajf, mdg}@uninova.pt, {algol, andre}sim.ul.pt

Abstract. An essential task when visualizing and analyzing large-scale 3D point cloud data is the selection of subsets of that data. This presents two challenges, the need for a selection method that is independent of the size of the dataset and how to interact with a 3D space effectively in a digital world still rooted in 2D interaction and visualization. We present an interface for defining volumes to select 3D point cloud data that uses hand gesture control with a Leap Motion device. The use of volumes is scalable to very large datasets, and the use of the Leap Motion gives the user access to the third dimension, facilitating interaction with the point cloud data. We illustrate with a large astronomical data archive hosted on the cloud that is retrieved on as-needed basis.

Keywords: Point Cloud Data, Gesture Recognition, Large Scale Data

1 Introduction

In an age when automated massive data analysis is becoming a mainstream activity, the task of visualization is essential for the understanding and critical interpretation of data and results – for science and mission analysis and control alike [1][2][3]. Particularly, in Space related activities, most of the data leading to new scientific discoveries is expected to come from online archives collected through automatic instruments and all-sky surveys. Very few works address the topic [4]. Unfortunately, no adequate visualization solutions are available today for interactively visualizing and analyzing such amounts of complex datasets. Within this context we present an interface for defining volumes to select 3D point cloud data that uses hand gesture control with a Leap Motion. The use of volumes is scalable to large-scale datasets, and the use of the Leap Motion gives the user access to the third dimension, facilitating interaction with the point cloud data.

When working with any data, it is often of interest to analyze the particular properties of subsets of that data. It is therefore necessary to be able to select the subset of interest. When properties of that data are already known, it is possible to use automatic processes to select it. Otherwise, some form of manual selection is necessary. If the data visualized is in the form of 3D cloud points, such data can only be selected in relation to its position, and therefore it is necessary to have an effective

method of spatial selection available. A challenge when designing such a method is how to define a 3D space easily when traditional interaction tools, such as a mouse or a touchpad are naturally geared towards 2D interaction. In cases where the point cloud dataset is too large to process in a single device and the data is stored on a distributed server, any solution must avoid the possibility of processing large chunks of the dataset.

Fig. 1. 3D selection using a touch-based interface [5]

Our goal is to design an interactive spatial selection method for a large-scale 3D point cloud visualizer. The method had to provide the user with the ability to select areas of the point cloud of any size without requiring the processing of large amounts of data.

The existing work related to selection of 3D point cloud data is not very extensive, and as far as we have been able to ascertain, does not consider the size of the dataset used [2]. One solution is to manually select 3D point cloud data by using a lasso to define a 2D area, as seen in Fig. 1, which then selects all points visible through it. This results in selections as seen in Fig. 2. This solution can easily result in selecting points that the user did not intend to select, and which then must be deselected similarly. Therefore, the selection becomes a complex multi-step process.
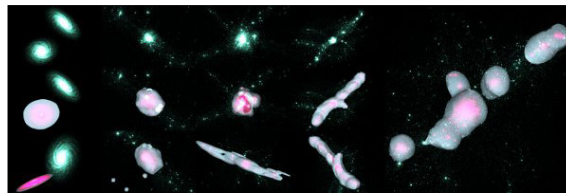

Fig. 2. 3D selection of galaxies using TeddySelection and CloudLasso techniques [5]

A paper by Lingyun Yu et al. [5] describes two solutions, TeddySelection and CloudLasso - two spatial, structure-aware selection techniques. They too rely on the use of a lasso, but they simplify the selection process by relying on algorithms to analyze the structure of the data and select a more limited area that is more likely to correspond to the user's needs. The performance of both techniques will scale with the number of particles to be selected, or even with the size of the whole dataset.

Another solution that has been used is the creation of volumes that encapsulate the point cloud data that the user wishes to select. One example is the 3D Point Cloud Editor [6], illustrated in Fig. 3. The volumes can be modified and multiple volumes can be combined using Boolean operations. This solution has the advantage of not requiring the processing of data to define the boundaries of its selection.

Fig. 3. Selection of points from a point cloud using a cuboid [6]

The Slice-n-Swipe [7] solution uses a Leap Motion and has the user perform gestures to define cuts in the point cloud and select the desired half. It introduces a 3D element into the selection process but allows only fairly simple selections to be made.

Finally, another proposed solution [8] uses a PrimeSense sensor for gesture recognition and an Occulus Rift for visualization, and selection is achieved by using the hand as a virtual brush to select the desired area of the point cloud.

Our solution combines gesture recognition to solve the problem of interaction with a 3D space by using a Leap Motion [9], with the data-independence of creating 3D volumes for selection. The Leap Motion provides the user with direct access to the third dimension, which otherwise can only be managed with complex multi-step processes or with the aid of data processing. This work is being developed in the context of a project, financed by the European Space Agency (ESA), denoted IVELA-Intelligent Visualization [10]. The project's main objective is to develop tools to support astronomers and physicists performing scientific visual analytics studies on gathered data, such as the mission GAIA [11]. The GAIA mission aims to map about a billion of the Milky Way's stars, and gather information about each of those stars, including their speed and direction. With this data they hope to learn more about the composition, formation and evolution of our Galaxy.

This paper is structured as follows. This first section and section 2 provide an introduction to the topic of research and its relation with the theme of the conference. Section 3 presents the prototype developed. Section 4 discusses the solution presented and its virtues and flaws. Section 5 briefly concludes the paper.

2   Contribution to Cloud-based Engineering Systems

As mentioned before, this work is being done as part of the development of an astronomical visualizer for large-scale stellar datasets [10]. Since a single computer cannot easily handle such large volumes of data, the data is stored in a cloud server and will be loaded as required. Scientists using the visualizer must be able to perform selections of clusters or regions of interest efficiently and effectively.

3   The Prototype

A prototype of the interaction system was created as a proof of concept of a tool for visual analytics. It was developed using the Unity game development system, developed by Unity Technologies [12] and programmed in C#. To allow interaction between the Unity application and the Leap Motion device [9], the Leap Motion C# API and Unity assets made by the Leap Motion company were used.

   The prototype environment displays a randomly generated cluster of stars. Using both hands to interact with the prototype through the Leap Motion, the point cloud stars can be selected by creating spherical or cubic selection volumes.

3.1   Interaction

The prototype displays 3D models representing the hands, as seen in Fig. 4. The movements of these models mirror the movements of the hands and fingers detected by the Leap Motion. This allows the user to more easily relate the movements of their hands to the effects to the environment in the prototype. The 3D model and their movement scripts used were part of the functionalities provided by the Leap Motion team.
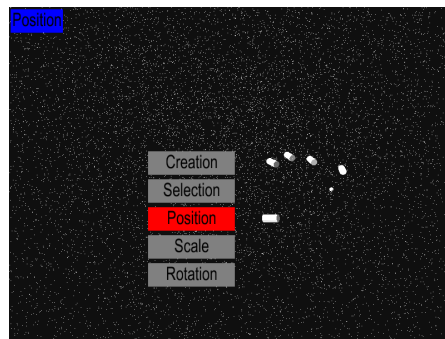

Fig. 4. The 3D representation of a hand.

3.2   The Modes

The interface is separated into distinct interaction modes, as follows:

- Navigation Mode
- Selection Mode
- Creation Mode
- Position Mode
- Rotation Mode
- Scale Mode

The user can choose which mode is active via a menu in the bottom of the screen, as shown in Fig. 4. By separating the various activities into different modes, the user can more freely interact with less risk of their gestures being misinterpreted.

3.3   The Menu

Using a simple command gesture, users can activate the menu at any point. The menu is composed of submenus that the user can activate by swiping left or right. Each of the submenus consists of a vertical list of buttons. To pick a menu option the user must move their hand up and down, highlighting the corresponding option, and then pinch their fingers together. Using the menus, the user is allowed to pick the active mode (Navigation, Selection, Creation, Position, Rotation or Scale) as seen in Fig. 4, switch to a mouse-based interface, pick the shape of the 3D volume they wish to create and change the visualization mode of the dataset.

3.3   Navigation Mode

Navigation within the prototype is based on the flight analogy. The user can move the camera forwards, backwards, left, right, up and down by moving the hand accordingly relative to the center of the Leap Motion's interaction volume, as well as rotate it along the horizontal and vertical axis by tilting the hand similarly.

3.4   Creation Mode

In creation mode either a spherical, cubical or cylindrical selection volume can be created. Two opposite sides of the volume are locked to the palms of two hands so that the user can freely move the volume and scale it by moving their hands within the 3D space. The user then locks the volume in place by pinching their index and thumbs together. This automatically switches the mode to the position mode. Fig. 5 shows a volume after creation.
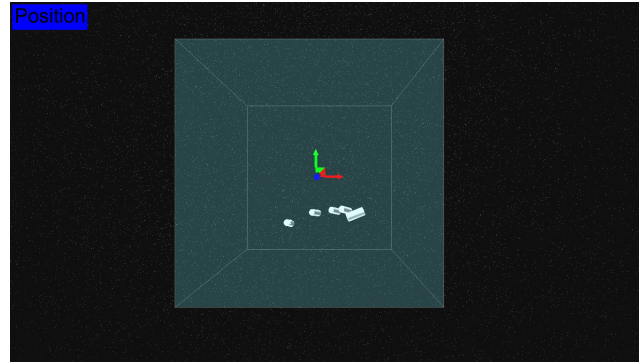
Fig. 5. A cubic selection volume after being created.

3.5   Position Mode, Rotation Mode and Scale Mode

The position, rotation and scale modes allow the user to edit the active selection volume. In the position mode, the user can move the selection by making a grabbing gesture with their hand and moving it. The volume moves in whichever direction the hand is in relative to the center of the device's interaction volume.

In the rotation mode, the user can rotate the volume by holding a pinching gesture and dragging the hands around, causing the volume to rotate in a corresponding direction.

In the scale mode, the user can increase or decrease the size of the volume along one of three axes by holding one hand at a height above or below the other. Using a gesture command they can switch between the three axes

3.6   Selection Mode

In the selection mode, the user can select volumes by pinching the index and thumb finger. The volume closest to the hand is selected. The selected volume can be deleted with a gesture command or it can be edited in the position, rotation or scale modes.

3.7   Visualization

When creating and editing a selection volume, one of the difficulties is to know which data points the volume is actually selecting. As such, visualization plays an important part in the process and several visualization modes were made available to the user:

- All: All data points are drawn.
- Only Selected: Only selected data points are drawn.
- Only Not Selected: Only non-selected data points are drawn.

- Colors: All points are drawn, but are given a different color depending on whether they are selected or not.

4 Discussion

While the Leap Motion can facilitate selection by giving the user the ability to interact with the software in three dimensions, there are still some limitations to its usage. The first problem is that the visualization is still two dimensional. The lack of depth perception associated with this means that it can be difficult to make a mental connection between the visualized space and the user's hands, rendering the advantages of 3D interaction far less effective. However, the available visualization modes help to solve this problem. For example, if the color visualization mode is active, then as the volume's position is changed, the effect on the selection is clearly visible.

The second problem is that the Leap Motion still has important limitations in its tracking ability. For example, it cannot keep track of a hand while it is occluded by another hand, limiting certain gestures in one axis. It also is limited in how many gestures it can easily identify. These problems raise many difficulties in designing sophisticated scientific visual analytics tool that users can understand intuitively and use effectively, and, therefore it remains   a simple interaction system. Indeed, we have not come across any user interface that uses the Leap Motion in a way that is not either trivially simple or very hard to master. However, new developments are expected in the near future and these might solve part of the pointed problems for developing a truly scientific visual analytics tool.

Despite its limitations, the use of the Leap Motion remains a more effective way of modifying the position of a 3D volume than any 2D interaction system. Any such system would require the user to refine the volume's position while changing position of the camera.

5 Conclusion

The selection method described in this paper is scalable, and intuitively simple to understand. Despite the current limitations of gesture recognition hardware and software, it holds a distinct advantage over systems that work purely with 2D tools.

However, there is still a long way to go before it can be considered a useful tool for any serious scientific work. Future developments could include the use of the Occulus Rift for improved visualization and the refinement of the gesture interface.

References

1. Bowman, D. A., Kruijff, E., La Viola, J. J., Poupyrev., I.: 3D User Interfaces: Theory and Practice, Addison-Wesley (2004)
2. Fisher, D.: Animation for Visualization: Opportunities and Drawbacks. In: Beautiful Visualisation, eds. Julie Steele & Noah Iliinsky, O'Reilly ed., pp. 338 (2010)
3. Hey, T., Tansley, S.: The Fourth Paradigm - Data intensive scientific discovery. Tolle, K. (eds.). Microsoft Research, Redmond. (2009)
4. Becciani, U., Costa, A., Antonuccio-Delogu, V., Caniglia, G., Comparato, M., Gheller,C., Jin, Z., Krokos, M., Massimino, P.: VisIVO-Integrated Tools and Services for Large-Scale Astrophysical Visualization. In: Publications of the Astronomical Society of the Pacific, v.122, i.887, p.119 (2010)
5. Yu, L., Efstathiou, K., Isenberg, P., Isenberg, T.: Efficient Structure-Aware Selection Techniques for 3D Point Cloud Visualizations with 2DOF Input. In: IEEE Transactions on Visualization and Computer Graphics, 18(12):2245–2254 (2012)
6. Li, Y., Hielsberg, M.: 3D Point Cloud Editor, http://paradise.caltech.edu/~yli/software/pceditor.html (2012)
7. Bacim, F., Nabiyouni, M., Bowman, D.A.: Slice-n-Swipe: A free-hand gesture user interface for 3D point cloud annotation. 3D User Interfaces (3DUI), 2014 IEEE Symposium on , vol., no., pp.185,186, 29-30 (2014)
8. Lubos, P., Beimler, R., Lammers, M., Steinicke, F.: Touching the Cloud: Bimanual annotation of immersive point clouds. In: Proc. 3DUI, pp.191-192 (2014)
9. Leap Motion, Inc., https://www.leapmotion.com
10. IVELA project, http://www.ca3-uninova.org/projects
11. European Space Agency, http://www.esa.int
12. Unity Technologies, http://unity3d.com