Designing Capsule, an Input Device to Support the Manipulation of Biological Datasets

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ABSTRACT

In this paper we present the design process of Capsule, an inertial input device to support 3D manipulation of biological datasets. Our motivation is to improve the scientist's workflow during the analysis of 3D biological data such as proteins, CT scans or neuron fibers. We discuss the design process and possibilities for this device.

Keywords: Scientific visualization, tangible Interaction, 3D interaction, input device.

Index Terms: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Direct manipulation, Haptic I/O;

1 INTRODUCTION

Interaction plays an essential role in the analysis of biological datasets. For example, scientists in molecular biology frequently use 3D computer models to understand the shape or to search for potentially interesting sites in macromolecules (e.g., DNA).

Existing software for this area usually relies on mouse and keyboard for manipulation. Recent work has shown the advantage of using 3D input along with domain-specific techniques. However, these approaches still build upon devices designed for generic tasks [4].

We propose Capsule, a tangible device with 3 degrees of freedom (DOF) for rotation and passive haptics for zooming, grabbing or mode selection. We present our design process and discuss its characteristics. First we discuss two closely related works.

2 RELATED WORK

Hinckley et al. [1] describes an interface for neurosurgical visualization. The authors use props as tools that can be positioned relative to a small head model. The tangible interface makes this approach familiar for surgeons and appropriate for some specific tasks like trajectory tracing and volume splitting. However, using two unconnected parts make it difficult to recover a specific reference frame once the hands are separated. Our device has a single part, which can be extended to indicate operations along an axis.

Jackson et al. [3] proposes a passive paper prop for the exploration of fibers from biological tissues. The prop is tracked by a depth camera. Unfortunately, this design suffers from occlusion and ergonomic issues since the user must make a constant effort to keep the prop in camera view. Our device uses inertial sensors, so the user can hold it in any comfortable position. Also, instead of indicating operations by sliding fingers over the prop, we use physical extension and pressure sensors.

3 DEVELOPMENT PROCESS

Our design process was based on ideation, domain expert participation and literature study. During the first iteration we sought to rapidly identify promising designs. Three ideas were selected and then evaluated using a low fidelity prototype. In the second iteration we refined the selected design and explored other possible ways to use the device.

3.1 Work Practice Analysis

In order to understand the activities and practices in the study of biological datasets, we carried out a contextual inquiry in the computational biology domain. It consisted of interview sessions and meetings with a domain researcher with five years of experience using the molecular biology software PyMol[1]. During the meetings we observed his actions in common research activities, focusing on how the visualization software and input devices were used to support analysis of the datasets. Once we had a clear understanding of the typical workflow, we generated a list with the most frequent tasks. This list was them validated and ordered by frequency with the domain expert assistance. Each task was further classified as: 2D menu operation, 3D selection or 3D manipulation (Table 1).

Rank	Task	Type
1	Select specific sequence	2D menu
2	Cut dataset	3D selection
3	Change visualization style	2D menu
4	Distance measurement	3D selection
5	Zoom into sites	3D manipulation
6	Atom selection	3D selection
7	Group atom selection	3D selection
8	Change colors	2D menu
9	Highlight atoms	3D selection
10	Select by secondary structure	3D selection

Table 1. List of the 10 most frequent tasks and the corresponding classification as 2D or 3D task. 3D selection and manipulation tasks are highlighted.

A subsequent task decomposition analysis indicated that all 3D selection tasks in Table 1 were preceded by a 3D manipulation (basically rotation and scale), necessary to place the dataset in an adequate orientation and distance for selection. We also did not list epistemic actions, where the user would manipulate the dataset only with the purpose of understanding it better. A lot of time was spent in this type of action, which further accentuates the importance of 3D manipulation.

During the interview we also identified, anecdotally, that scientists in this area routinely perform gestures while talking

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[1] https://www.pymol.org/

IEEE Symposium on 3D User Interfaces 2016
19–23 March, Greenville, SC, USA
978-1-5090-0842-1/16/$31.00 ©2016 IEEE

about structural aspects of the data. This seems to be a consequence of the lack of materiality of the data and the lack of a convenient way to indicate features during discussions.

3.2 Design

Our design began by exploring the design space through brainstorming, storyboarding and literature review. The domain expert participated in the brainstorm sessions, which had a lot of sketching and demonstration with the hands. We also reviewed the literature for claims that could be applicable to our tasks.

Three ideas were selected for a final round: two bare-handed techniques (using one and two hands) and a third involving a tangible device. After analysing pros and cons, we settled in favour of the tangible interaction. Three claims were instrumental in supporting this decision:

- Two handed input offers manual and cognitive advantages [5]. Manual benefits come from increased time-motion efficiency, while cognitive benefits arise as a result of the reduction of the mental load involved in task composing and visualization.
- Passive props increase the level of control and understanding when working with three-dimensional data visualization [3].
- Direct manipulation offer a more satisfying experience and also enable people to better concentrate on their tasks [6].

We chose the metaphor of holding a device that represents the data visualized on the screen. In that way the dataset could be oriented easily in any direction. Instead of using a generic spherical shape, we chose a cylindrical form factor to allow the user to maintain a tactile reference vector [2]. To support zooming we added two sliding covers. The user can grab on both sides and pull or push to change the dimension of the dataset on the screen.

To decide the physical dimensions, we compared the feel of manipulating different cylindrical objects. We found that a radius of ~50mm would allow a comfortable grasp while still offering internal space for electronics. Regarding the length, we found that extending from 115 mm to 140 mm provided a reasonable feedback without being too long or too short (Figure 2).

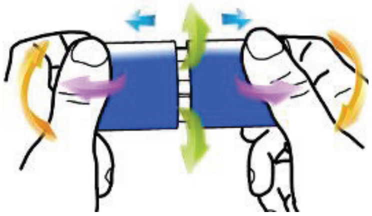

Figure 1. Illustration of handling pose and available DOF

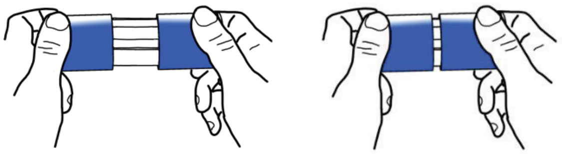

Figure 2. The sliding mechanism: a) open configuration, b) closed configuration

This sliding mechanism can be used to support different metaphors such as:

- Holding an object at two extremities and pulling them apart to zoom or scale;
- Opening or slicing a volume to reveal the contents inside the capsule;
- Grabbing something with your both hands when covers are near and releasing when far.
- Point and adjust scalar values (this is a single hand grab where the cover is controlled using the thumb and index finger).

Since some tasks we identified need at least some basic selection capabilities, we included two independent pressure sensing areas around the outer half of each cover. They can be used as a clutch for the model or as buttons to alternate between visualization styles. The placement makes them available most of the time, regardless the orientation of the device and without disrupting the shape of the surface.

Capsule can be described as a device with 3 DOF free space rotation, 1 DOF egocentric isotonic position (sliding), 2 DOF isometric rate control (pressure sensors). Relative position control is easy to support by using the sliding mechanism or the pressure sensors as a clutch. The integrality of the rotation control makes the device adequate for orientation tasks. In fact, as long as the biomechanical restrictions of hand and arm are respected, it can support 4 DOF integral tasks (simultaneous sliding and rotation).

4 CONCLUSION AND FUTURE WORK

In this paper we show how we can use characteristics of the target domain to create more intuitive and efficient input devices. We present the design of Capsule ax`xxxxxnd examine some of the ways it can be used to support exploratory analysis tasks.

We presented the final design to several researchers in the molecular biology domain and received positive feedback. As future work we would like to build an actual device and perform a user study in the target domain.

5 ACKNOWLEDGEMENTS

The authors wish to thank the anonymous reviewers for their input. This work was supported by NSF (1320046, 1319606 and 0938047) and the Brazilian National Council for Scientific and Technological Development.

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