Interactive Volume Perceptualization System

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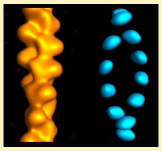


Introduction

In this paper, we present a multi-modal data perceptualization system used to analyze the benefits of augmenting a volume docking problem with other perceptual cues, particularly stereoscopic vision and haptic rendering. This work focuses on the problem of matching complex three-dimensional shapes in order to reproduce known configurations. Specifically, we focus on the docking of two proteins, actin and cofilin, responsible for cellular locomotion.

Despite significant progress in computational models and techniques for data perceptualization, much work remains for the quantitative evaluation of data perceptualizaiton systems in terms of their effectiveness in transmitting information to the user. Moreover, researchers and scientists have been slow in adopting the new technologies. In light of this, there is a pressing need to quantify the usefulness of data visualization systems in order to demonstrate their applicability to scientists.

IVPS: Interactive Volume Visualization System

Our research group recently developed an Interactive ***Volume Illustration System (IVIS)*** to create illustrations of three-dimensional datasets. IVIS provides a graphical user interface in which the user can easily control the shape of the transfer function. By applying the user-defined transfer function to the dataset, IVIS can instantaneously update the visual representation, enabling the user to interactively explore the dataset.

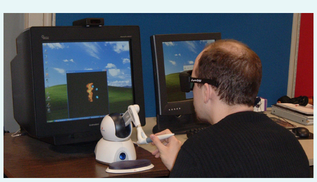
We have extended IVIS into an Interactive ***Volume Perceptualization System (IVPS)*** providing:

- The simultaneous rendering of multiple volumetric datasets
- Stereoscopic images using active stereo vision
- The sense of touch via a force-feedback haptic interface
- Interactive transfer functions for both vision and touch

Experimental Design

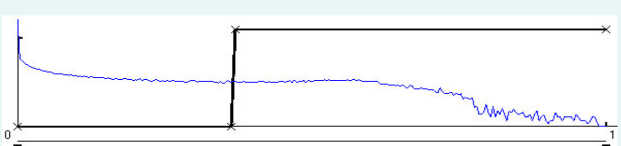
Users were shown examples of cofilin combining with actin and asked to reproduce this match. Accuracy of the match and completion time were measured and analyzed in order to quantify the benefits of augmenting tools for such a task.

Experimental Conditions

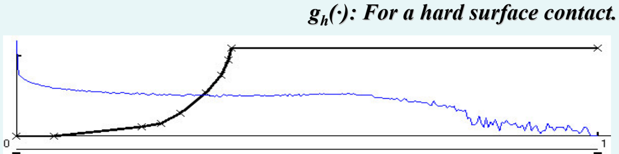


Condition	Visual	Haptics
C1	Mono	None
C2	Mono	$g_h(.)$
C3	Mono	$g_s(.)$
C4	Stereo	None
C5	Stereo	$g_h(.)$
C6	Stereo	$g_s(.)$

Actin and cofilin models used in the experiment

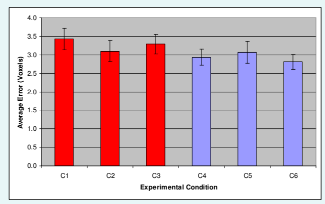


$g_h(\cdot)$: For a hard surface contact.

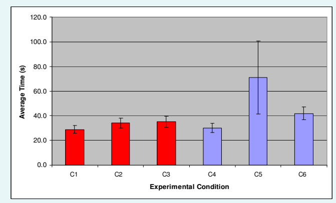


$g_s(\cdot)$: For a volumetric soft contact.

Experimental Results



Docking error

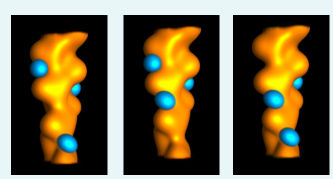


Completion time

- Using stereo vision (C4-C6) generally reduced the error as compared to mono vision (C1-C3). Using stereo vision (C4) showed a statistically significant decrease in docking error compared to using only mono vision (C1). C4 reduced the error found in C1 by 0.8 voxels, which corresponds to approximately 4 mm in the PHANToM workspace.
- Using all the enhanced features of IVPS (C6 with stereo vision and $g_s(.)$) showed a statistically significant decrease in docking error compared to using mono vision (C1). C6 reduced the error found in C1 by 1.1 voxels, which corresponds to approximately 5.5 mm in the PHANToM workspace.
- From the completion time data shown, we can observe that adding force-feedback tended to increase the overall response time (C2, C3, C5, and C6) as compared to the purely visual conditions (C1 and C4). Each of C3, C5 and C6 indicated a statistically significant increase in completion time as compared to C1. This can be explained by the fact that haptic perceptualization is achieved by local and sequential explorations of an object, while visual perception is global and parallel.

Discussion and Conclusion

It is not clear which haptic rendering method produced the most accurate fit as no other conditions showed a statistical significance compared to C1.



However, the results show a trend toward better accuracy using *gs*(.) with stereo. We plan to investigate this further.

There are many more haptic transfer functions that could have been used for the current dataset. The state-of-the-art in haptics research does not provide general guidelines on how to design haptic transfer functions that can aid the user of a data perceptualization system to perform a task well.

PURPL Purdue University Rendering & Perceptualization Lab

Haptic Interface Research Laboratory

world HAPTICS conference Pisa, Italy March 18-20, 2005