A VR-based surgical simulation system using patient- specific physical computing model

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Purpose

Apart from the applications in surgical navigations, virtual surgery has become a new feasible method for training young surgeons. Since 2006 virtual simulation has been performed in selected patient cases affected by complex craniomaxillofacial disorders (n = 8) in addition to standard surgical planning based on patient specific 3d-models. [1] Although for training, standard models are enough for young surgeons to practice, we still need to build an accurate and personalized model to simulate a surgery better.

Patients' CT images are considered appropriate references for this procedure. CT images are taken along the axis of the body, and each of them represents the structure of a plane that is perpendicular to the body axis. Information like the gray scale levels of each pixel, which can be used in building a volume model, are also contained. During an operation, the model should be able to give some haptic feedback as well as to update the changes on the models in real time.

In this project, we realize these functions with CHAI3D library. Omega 6 is the device we use for applying forces and receiving feedbacks.

Hardware and Software implement

Designed as a platform agnostic framework for computer haptics, visualization, and interactive real- time simulation, CHAI3D is an open source framework that supports a variety of commercially-available three-, six- and seven-degree-of-freedom haptic devices, and makes it simple to support new custom force feedback devices. [2]

The omega.6 is the most advanced pen-shaped force- feedback device available. The combination of full gravity compensation and driftless calibration contributes to greater accuracy. [3]

Methods

In particular, we use the voxel data to determine the shape of the model and then create it in the CHAI3D world. CHAI3D allows users to load a stack of CT images into a multi-image pointer and analyze them. After creating a CHAI3D world and allocating the voxel data for them, we set an isosurface level to the object, and those voxels which gray level values exceed the isosurface level will represent unit points and form the model.
Collision detections and haptic feedback are also added to the model. CHAI3D uses a virtual "finger-proxy" algorithm to compute forces. When a tool object hit the surface of a model, the tool we can see will stop moving directly into its goal. However, the proxy of the tool is actually able to stick into the object, which is shown in the figure below. In this case, forces are computed between the actual tool and its proxy, assuming a string in the middle trying to drag them back together. Users can define the stiffness of the model according to the materials.

When users click on the switch on Omega 6 while the virtual tool hit the object, the drilling operation is started. CHAI3D will read the collision event, and the determine the point which is contact with the tool. Then, the property of the point is changed, and it is no longer visible and able to give any haptic feedback. Graphic rendering will occur at the same time, and users can know about the result of their operation immediately.

Results and Conclusions

At present, some core functions such as loading image files, creating volume objects, and modify objects are completed. Right now, users can drill on models at random directions, and models can update its data and graphics in real time. Simple textures and haptic feedback are also applied on the models. Furthermore, for better simulations, we will calibrate the haptic feedback, restrict the drilling directions, and improve rendering through using colormap in the model. We expect this virtual surgery program can simulate cutting, grinding and even more complicated operations. Therefore, surgical training can be feasible and thus save time and cost in surgery practicing.

References and Acknowledgement

[1] Adolphs, Nicolai, et al. "Virtual planning for craniomaxillofacial surgery–7 Years of experience." Journal of Cranio-Maxillofacial Surgery 42.5 (2014): e289-e295.
[2] http://www.chai3d.org/concept/about
[3] http://www.forcedimension.com/products/omega-6/overview

This work was supported by Natural Science Foundation of China (Grant No.: 81511130089), Foundation of Science and Technology Commission of Shanghai Municipality (Grant No.: 14441901002, 15510722200, and 16441908400).

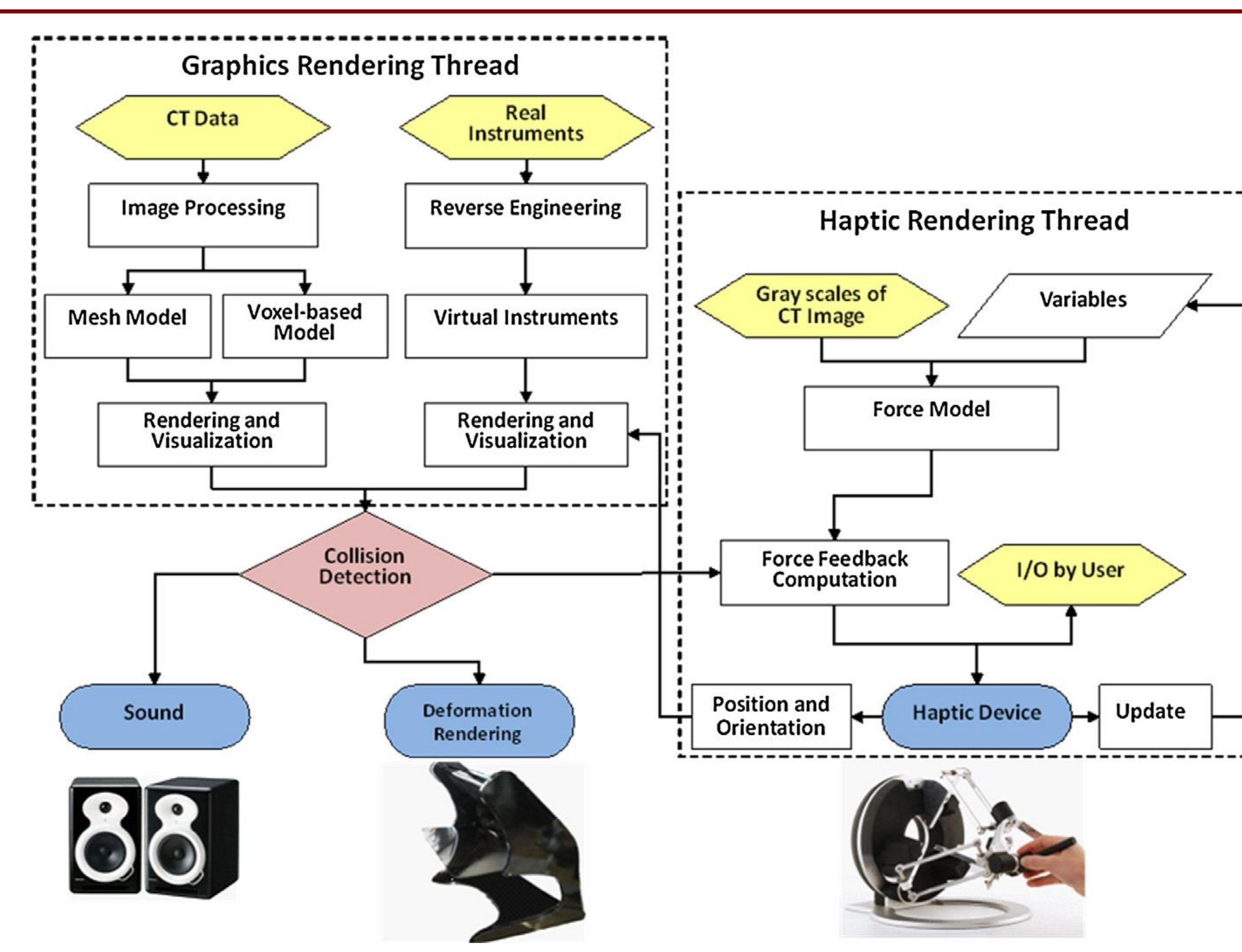

Fig. 1 Construction of the surgical simulation program

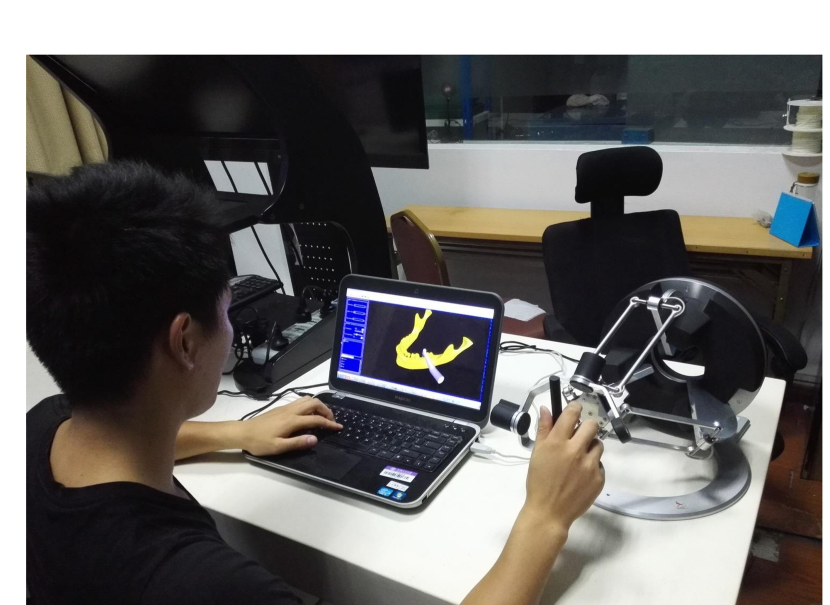

Fig. 2 Program interface and Omega 6

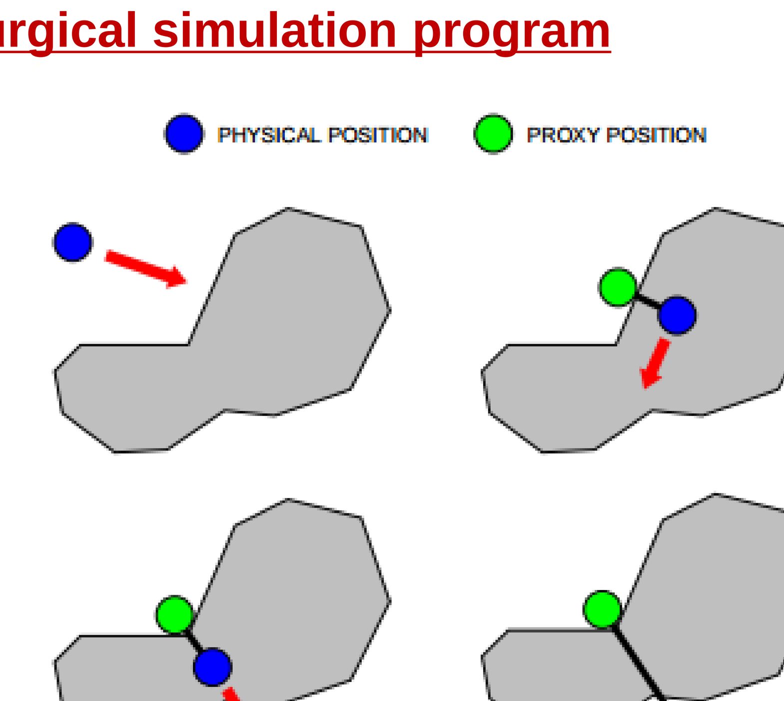

Fig. 3 Motion of the virtual proxy in Finger-proxy algorithm

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SMIT 2017
29th Conference of the international Society for Medical Innovation and Technology