Visualization of Blood Platelets in a Virtual Environment

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We have developed an interactive system using an immersive environment to visualize results from simulations of blood platelets in the flow through small blood vessels. Contributions of this work are the first 3D stochastic simulation and visualization in a virtual environment of platelet aggregation.

1 Introduction

Platelet aggregation is important for closing the minute ruptures in small blood vessels that occur hundreds of times daily, but may also lead to arterial occlusion in the setting of atherosclerosis and trigger disease such as myocardial infarction. Platelet aggregation involves platelet activation due to vascular injury, cell-cell interactions, platelet-vessel walls and platelet-thrombus interactions.

We visualized the results of simulations of platelets in small blood vessels in an interactive immersive virtual environment. Our hope was to increase the intuition of 3D platelet data by using a 3D display, a CAVE environment. Previously the simulation results were visualized using commercially available software Tecplot from Amtec Engineering, Inc. Tecplot can display a large number of platelets on a standard computer monitor. As in the case with most 3D data, the visualization of 3D platelets is not easy on a 2D display.

2 Methods

We have developed a stochastic version of the the Force Coupling Method [Maxey and Patel 2001] which employs multipole expansions to model platelets in small blood vessels. We created a mesh, consisting of a cylindrical section of a blood vessel, and generated preprocessed simulation data for discrete timesteps. Different colors were assigned to the 3 biological states of platelets being modeled: passive, pre-active, and active.

This project has extended the particle-visualizer framework that was used in [Sobel et al. 2004]. The user interface consisted of a set of headtracked stereo glasses and a 3-button wand. Using the wand, the user was able to access a menu, grab the world to navigate around, and cycle through various preset viewpoints in the scene. It also provided convenient access to timestepping and speed controls, which were essential in being able to effectively and thoroughly control and examine the animation of the data.

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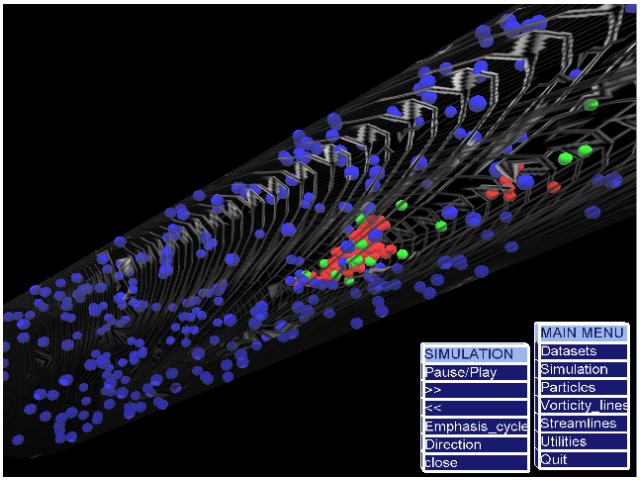

Figure 1: An outside view of the blood vessel with an aggregate formation. Being in the CAVE allows users to observe platelets while being directly inside the blood flow. Activated platelets are shown in red, pre-activated in green, and passive in blue.

3 Results

Our visualization tool allows the user to observe the platelets in three-dimensional unsteady flow while being directly inside the simulated blood vessel. Using intuitive body movements, such as ducking, looking up, and moving side to side to observe different perspectives of the platelet data is effective and easy to adapt to. It is easy to follow each platelet, its interactions with other cells, platelet aggregate or vessel walls. By controlling the speed of visualization and playing backwards, if necessary, the user can study these interactions more precisely. The visualization system was evaluated by scientific users and got a positive feedback. The feedback included statements such as the model was simple and straightforward, and it presented a new phenomenology that was a good way to look at platelet data with greater insight. To the best of our knowledge, this is the first ever 3D stochastic simulation and visualization of platelet aggregation.

References

MAXEY, M., AND PATEL, B. 2001. Localized force representation for particles sedimenting in stokes flow. *Int. J. Multiphase Flow 9*, 1603.

SOBEL, J., FORSBERG, A., LAIDLAW, D. H., ZELEZNIK, R., KEEFE, D., PIVKIN, I., KARNIADAKIS, G., RICHARDSON, P., AND SWARTZ, S. 2004. Particle flurries: Synoptic 3D pulsatile flow visualization. *IEEE Computer Graphics and Applications 24*, 2 (March/April), 76–85.