Toward Development of a Forensic Visualization Lifecycle Management System

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ABSTRACT

In this project, we are going to develop a forensic visualization lifecycle management system, where leading-edge informatics technologies, such as provenance management, augmented reality and affection estimation, are integrated to allow the users with different roles to visualize investigated crime data in a first-person manner for clarifying points of dispute in court. In this first-year report, we place a particular focus on realtime 3D simulation of bleeding as an integral part of functionalities to be provided by the developed system.

1. Introduction

We build upon a commonly-used Lagrangian method, called SPH (Smoothed Particle Hydro-dynamics) to faithfully simulate bleeding on human skin surface, which is inevitable to reproduce stabbing incidents from investigation information.

Salient features of the SPH simulation are three-fold:

(1) bleeding from wounds modeled along with in vivo blood flow reflecting their geometry;
(2) congelation of blood represented by varying viscosity according to the time exposed to the air;
(3) adherence to the skin surface formulated by an additional adsorption term due to van der Waals force introduced to the original Navier-Stokes equations.

2. Methods

2.1 Bleeding from wound

The shape of a wound on the skin surface is defined by user-input strokes, and its depth and width are determined automatically by the type of estimated blade. Then, a simple in vivo blood flow model (Fig. 1) is evaluated within the resulting prismoid, where an acceleration is directed in parallel to the skin surface normal. When colliding with an exit polygon, the particle bleeds.

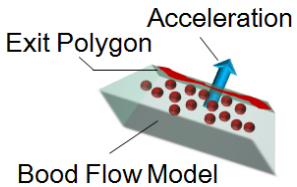
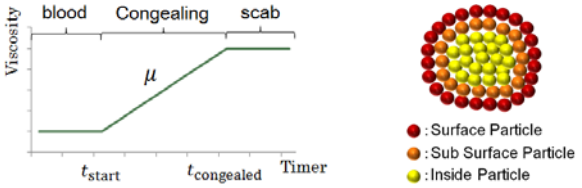


Fig. 1 A simple in-vivo blood flow model.

2.2 Congelation of blood

After bleeding from the wound, blood starts to contact with the air and clot through the action of platelets. This phenomenon can be represented by changing the viscous force of each particle of the blood according to the time exposed to the air, as shown in Fig. 2. Any particle can be classified into the three phases depending on the distance from the blood surface at each time step, and a particle closer to the surface is modeled to clot faster by moving forward its congelation timer.



(a) time-varying viscosity (b) particle class

Fig. 2 Changing viscosity of particle according to the degree of exposition to the air.

2.3 Adherence to skin surface

Blood's adherence to the skin surface and sliding even underneath a lower-horizontal surface can be explained as a sort of physisorption due to van der Waals force. Clavet et al. 2005 [1] added an attraction force term formulated by a quadratic function for each particle to have antigravity nature, whereas the formulation appears to lack the physical basis, and thus cannot express the adherence of blood to the skin very well. Since van der Waals force is inversely proportional to the seventh power of the distance between the objects, we re-formulated the adsorption force by:

$$f_i^{adsorb} = -\rho \frac{k}{(d_i - d^{adsorb})^7} n, \qquad (1)$$

where ρ denotes the particle density, d_i the distance between particle i and the skin surface, and n the surface normal. If d_i is smaller than d^{adsorb}, the force becomes an infinity.

Adding the adsorption force in Eq. (1), a relatively strong force acts onto the skin surface. If we still rely on the traditional SPH collision process, which updates the particle velocity only with the drag and friction coefficients, the particles would be flown in unintended directions. Therefore, after detecting the particle's penetration into the skin surface, the position of the colliding particle is projected feasibly onto the surface with its velocity set to 0.

However, it may terminate the blood flow, because each particle tends to continue staying at the same place. To address the problem, we also considered the saturation of adsorption sites, where if there are more than a certain number of adhered particles, remaining particles are forced to slip through, as shown in Fig. 3.

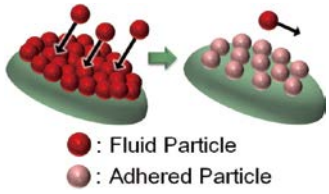


Fig. 3 Handling the case with saturation of adsorption.

3. Implementation and Results

We defined the blood surface using the zero level set method in a similar way as in Adams et al. 2005 [2]. The fluid surface mesh was extracted using an accelerated Marching Cubes algorithm, and rendered with an open-source ray-tracer named POV-Ray ver. 3.62. All the simulations and visualizations were carried out on a standard PC (Intel Xeon E5540 2.53GHz CPU, 12GB RAM, and Quadro FX 4800 GPU). In the current codes, the in-vivo simulation and surface reconstruction phases have been parallelized on the GPU.

Fig. 4 contains three independent sequences of resulting images, in order to prove how faithfully our codes can reproduce bleeding scenes. Fig. 4(a) delineates the bleeding from a wound on the forehead getting adhered and sliding even underneath a lower-horizontal surface due to physisorption. Fig. 4(b) visualizes the congelation effect through pseudo color coloring, which changes normal blood's color to translucent red and scab's color to opaque blue. In Fig. 4(c), we assumed that the volume per particle is 6 $\mu\ell$, and about 2.0 $m\ell$ blood (300 particles) was generated every second from each of the wounds. What can be observed from the image sequence is the complicated merge and split patterns and dynamics of blood streaks reflecting the face and wounds' geometry. The simulation ran at a rate of 7.4 FPS to yield the result shown in middle snapshot on the above-mentioned PC. For more details, consult the latest paper [3].

4. Concluding Notes

In this initial report on the project, we have proposed a particle-based approach to visual simulation of bleeding on skin surface. Although our current simulation design policy is to trade physical accuracy for visual reality and to be suited for the use in the augmented reality environment, more physiologically-precise settings of hemorrhage volume and congelation speed would extend the proposed scheme so as to be applied to practical visual analysis for forensic purposes.

References

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(a) Physisorption effect.


(b) Congelation of bleeding from a simple wound.


(c) Complex pattern of bleeding from three wounds.

Fig. 4 Simulation results.