

Realistic Irrigation Visualization in a Surgical Wound Debridement Simulator

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Background/Problem

Wound debridement refers to the removal of necrotic, devitalized, or contaminated tissue and/or foreign material to promote wound healing. Surgical debridement uses sharp instruments to cut dead tissue from a wound and it is the quickest and most efficient method of debridement. A wound debridement simulator [1] can ensure that a medical trainee is competent prior to performing a procedure on a genuine patient.

Irrigation is performed at different stages of debridement in order to remove debris and reduce the bacteria count through rinsing the wound. This paper presents a novel approach for realistic irrigation visualization based on texture representations of debris. This approach applies image processing techniques to a series of images, which model the cleanliness of the wound. The active texture is generated dynamically based on the irrigation state, location, and range.

Tools and Methods

Texture mapping is a standard and powerful rendering technique used in modern computer graphics and it enhances realism and details in a scene with only a modest increase in computational complexity. Texture mapping lays one or more digital images onto a surface or volume.

In the proposed approach, the wound cleanliness is modeled by a series of images, simulating a variety of debris on the contaminated wound; however, at any time, there is only one texture active over the whole mesh. The active texture is initialized to be the dirty image and updated dynamically at different stages of the surgical debridement, as a result of combination of several different images.

Denote the active texture as T , and the images representing dirty state and clean state as I_d , I_c , respectively (The irrigation is simplified into only two states in this abstract). The steps in the irrigation are as follows:

1. At the beginning of irrigation, let $T = I_d$.
2. During irrigation, detect the possible intersection between the wound and the prolonged syringe outline. Compute the intersection point P and the triangle that contains P . Assuming the three vertices of the intersected triangle has geometrical coordinates $\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3 \in \mathbb{R}^3$ and texture coordinates $\mathbf{t}_1, \mathbf{t}_2, \mathbf{t}_3 \in \mathbb{R}^2$, the texture coordinate \mathbf{t}_p of P can be computed as follows:

$$\mathbf{t}_p = \frac{\sum_{i=1}^3 a_i \mathbf{t}_i}{\sum_{i=1}^3 a_i},$$

where a_i , $i = 1, 2, 3$, are the barycentric coordinates of P , expressed as a convex combination of $\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3$.

3. Assuming that the sizes of the texture and the images have been normalized into the range of $[0,1] \times [0,1]$, the texture T is updated as follows

$$T(\mathbf{t})_{\|\mathbf{t}-\mathbf{t}_p\| \leq r} = (1-c)I_d + cI_c,$$

where r is the range of irrigation and c is a coefficient that determines the thoroughness of the irrigation.

Other critical techniques in the irrigation visualization include utilization of OpenSceneGraph [2], which is a high-performance 3D graphics toolkit, and the development of collision detection algorithms, which is omitted in this abstract due to space constraint.

Results

The irrigation results are shown in the figures that follow. Fig. 1 shows a simplified dirty wound with some dirt on the wound. Fig. 2 shows the triangular mesh of the thigh used in the wound debridement. The wound is being cleaned in Fig. 3; it can be seen that the boundary between the dirty area and the cleaned area is smooth, eliminating blocking or mosaicing artifacts exhibited by our previous work. Fig. 4 shows the wound after cleaning, which is ready for further operations such as cutting dead tissue in the wound debridement.



Fig. 1 Dirty wound

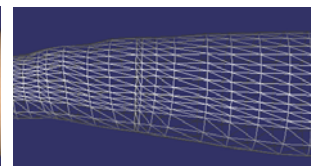


Fig. 2 Mesh for the wound

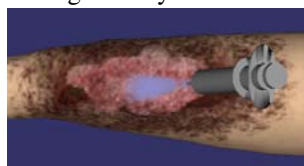


Fig. 3 Dirty wound is being cleaned Fig. 4 Clean wound

Conclusion/Discussion

A novel approach for realistic irrigation visualization in a surgical wound debridement simulator is proposed, utilizing image processing techniques in a series of images modeling the wound cleanliness. The result is highly realistic and the algorithm is simple to implement with low cost.

References

- [1] J. Seevinck, M. Scerbo, L. Belfore, L. Weireter, J. Crouch, Y. Shen, F. McKenzie, H. Garcia, S. Girtelschmid, E. Baydogan, and E. Schmidt, "A Simulation-Based Training System for Surgical Wound Debridement," Medicine Meets Virtual Reality 14, Long Beach, CA, Jan. 2006. Submitted.
- [2] OpenSceneGraph, <http://www.openscenegraph.org>