Visualization of Treatment Evolution Using Hardware-Accelerated Morphs

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Abstract. The observation of the evolution of a course of treatment can provide a powerful tool in understanding its efficacy. To visualize this, we produce animations allowing the visualization, as a function of time, of lesions in an organ. Such animations can be used in teaching or for patient education, influencing a patient's decision of following a course of treatment. The animation produced is a metamorphosis, or morph, describing how a source shape (pre-treatment) gradually deforms into a target shape (post-treatment). We implemented our method using the programming capabilities of current graphics cards (also known as graphics processing units or GPUs), so both visualization of the volumes and morph generation are performed in real-time. We demonstrate our method on data from a patient's liver with lymphoma that was treated with chemotherapy and is currently on remission.

1. Introduction

The observation of the evolution of a course of treatment can provide a powerful tool in demonstrating or understanding its efficacy. To perform this, we produce animations allowing the visualization, as a function of time, of lesions in an organ. Such animations can be used in teaching or for patient education, influencing a patient's decision of following a course of treatment.

The animation generated is a metamorphosis, or morph, that describes how a source shape (pre-treatment data set) gradually deforms into a target shape (post-treatment data set). We chose to use implicit morphs, where an implicit function describes the changing geometry and the intermediate shapes are defined by the level sets [5] of the function at different time points. These intermediate shapes are defined by interpolating between signed distance functions (also called distance fields) of the source and target shapes. The magnitudes of these distance fields indicate the distance from the surface of the shape, while the sign indicates where a point is inside or outside of the shape.

The fast rate at which the hardware of graphics cards (also known as graphics processing units or GPUs) are evolving, especially the development of their programming capabilities, opened up the possibility of implementing several graphics-related applications using GPUs, thus speeding up their executions. In this paper, we advocate the use of GPU programming to accelerate the visualization and morphing of medical 3D objects, so they can be done interactively in real-time.

2. Method

Our method for creating the morph animation is divided in three steps: segmentation of the target organ in the data sets, registration of the data sets, and generation and visualization of the morph.

The method used for segmenting the data sets is the multiseeded fuzzy segmentation of [2], a region growing method, that based on user input, in the form of seed *spels* (short for spatial element), produces a connectedness map that encodes the grade of membership of every spel to the segmented objects. The grade of membership of a spel c to an object m, a real value between 0 and 1, reflects the confidence that the method's solution has that the spel c belongs to the object m. This map is then thresholded for the object associated with the target organ/lesions to isolate the objects to be visualized in the morph sequence.

The last two steps of our method are performed using the interface Imorph [3]. In the registration step, the two volumes (pre-treatment and post-treatment) are visualized, so the user can align them and chose correspondence points between them. These correspondence points can then be used to generate a non-linear warping map that is applied to both volumes using dependent textures, in a similar manner as in [7].

The generation of the morph between two shapes A and B is obtained by cross-dissolving the distance fields (that encode the distance from each point to the surface of the object) of the two shapes, resulting in a linear interpolation between the source and target distance fields [4]:

$d = (1-t) * \mathrm{dist}(A) + t * \mathrm{dist}(B),$

where $\mathrm{dist}(A)$ is the signed distance field for the shape A, $\mathrm{dist}(B)$ is the signed distance field for the shape B, and d defines the intermediate shape at time t. As t is varied, for $0 \le t \le 1$, intermediate shapes are extracted where the interpolated distance field d evaluates to zero. At the starting time ($t = 0$) the resulting shape is completely defined by the source shape A, and at the ending time ($t = 1$) the resulting shape is completely defined by B.

After the distance fields are interpolated for a value of t, the intermediate shape can be visualized in real-time by performing its volume rendering using the algorithm of [6]. The renderings of intermediate shapes in incremental steps of t generate the final morph sequence. The algorithm of [6] uses the graphics hardware to perform volume rendering by storing distance fields as textures, computing the intersection of planes parallel to the image plane with the texture volumes, and rendering these texture planes in back-to-front order (from the farthest plane to the closest one).

3. Experiment

The experiment shown in Figure 1 depicts the evolution of a liver treatment for a patient that suffers from lymphoma, was treated with chemotherapy, and is currently on remission.

After the data were segmented, the objects of interest in the segmentations (the liver and pre- and post-treatment lesions) were isolated, with the segmentation step taking around 60*s* per data set (on a Pentium 4 3GHz). Then, their distance fields were calculated, in a procedure that took around 20*s* for each of the three objects, and stored in three different 3D textures in the memory of an NVidia GeForce FX 5950 graphics card. (It is important to note that the graphics card used in this experiment is an off-the-shelf card that usually is shipped with medium-priced PCs.)

After the segmentation and the initial distance field computation, all other operations are performed in real-time, allowing the user to change the viewpoint during the morph sequence.

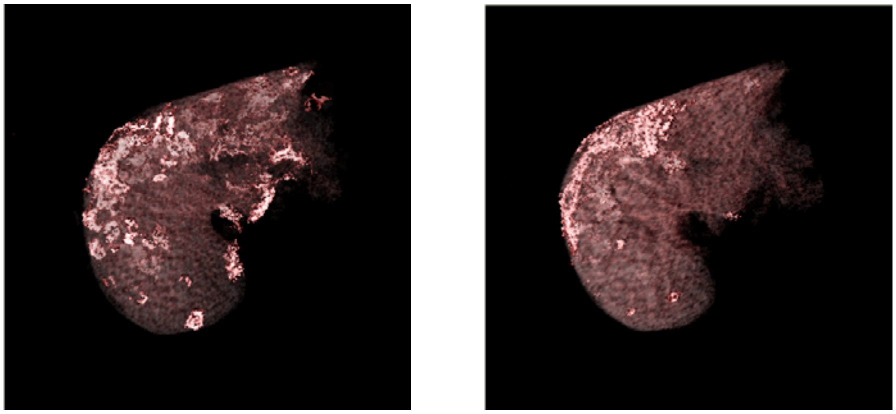

Figure 1. Volume rendering of the pre- (left) and post-teatment (right) stages of a patient's liver affected by lymphoma.

4. Conclusion

In this paper, we advocate the use of morphs for interactive real-time visualization of the evolution a treatment. Morphing can be a valuable tool that can be used to observe the dynamics of treatments, for example, in tracking the evolution of lesions over time as affected by treatment. Other applications include the interactive visualization of activity in functional imaging and the generation of new data sets from available ones for their use in education [1].

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References

[1] Bergeron, B., L. Sato, and R. Rouse. "Morphing as a Means of Generating Variation in Visual Medical Teaching Files". Comp. in Biol. and Med., 24:11-18, 1994.

[2] Carvalho, B.M., and G.T. Herman. "Multiseeded Segmentation Using Fuzzy Connectedness", IEEE Trans. on Pat. Anal. Mach. Int., 23:460-474, 2001.

[3] Cohen-Or, D., D. Levin, and A. Solomovici. "Three-Dimensional Distance Field Metamorphosis", ACM Trans. on Graph., 17:116-141, 1998.

[4] Dinh, H.Q., and Carvalho, B.M. "Imorph: An Interactive System for Visualizing and Modeling Implicit Morphs", TR CS-2004-08, Dept. of Computer Science, Stevens Institute of Technology, 2004.

[5] Payne, B.A., and A.W. Toga, "Distance Field Manipulation of Surface Models", IEEE Comp. Graph. and Appl., 12:65-71, 1992.

[6] Westerman, R., and Ertl, T. "Efficiently Using Graphics Hardware in Volume Rendering Applications", Proc. Of SIGGRAPH 98, 169-177, 98.

[7] Westerman, R., and Rezk-Salama, C. "Real-Time Volume Deformations", Computer Graphics Forum, 20:3, 2001.