

Prostate Visualization with Overlapping Regions of Interest

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ABSTRACT

We have developed a system to allow for the 3D visualization of prostate MRI data and CAD results, referred to as score values. In this system, it is also possible for the user to paint custom regions in custom colors on the 2D slices and view these regions in the 3D rendering. While it was possible for the user to maintain visibility of a specific score value in the previous version of our system, with a distinctive tinting when two scores overlapped, such a method would not be applicable to the user painted regions. In this work, we explore a method to allow these user painted regions to remain visible when they would otherwise be occluded, while still maintaining a visual cue when the custom region overlaps with a score value. In order to be color independent, this visual cue is provided as a striped pattern on the surface rather than using a predefined color for tinting. The rendering results remain interactive using GPU-accelerated ray casting.

Index Terms: I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1 INTRODUCTION

Prostate cancer is one of the most prevalent cancers worldwide [4]. Recently, the use of magnetic resonance imaging (MRI) has been explored as a method of locating the cancer within the gland [2]. In doing this, there are two main modalities which provide good images of the gland. T_2 -weighted images are used to identify cancer. T_1 -weighted images are used to identify hemorrhages, which can appear as cancer in T_2 -weighted images. Other MR images have also been explored, but these two are the most common and the focus of this work.

Two tools useful for a user when exploring the prostate are methods for indicating regions of interest within the volume and importance rendering when viewing multiple types of data at the same time. Previously, work on editing volumes has focused on various ways of displaying the existing data, such as painting on surfaces and making annotations, cutting windows within structures, or selecting regions to render differently [5]. In terms of importance-driven rendering, composition could be performed in such a manner that it presents the important structures when they might otherwise be obstructed [1].

We have previously explored the basis for developing a visualization system to view multiple scan types at once in 3D [3]. In that work, score volumes were created to hold the results of any generic computer-aided detection (CAD) scheme. These score volumes would be created separately, for example, for T_2 -weighted and T_1 -weighted images, and then could be visualized individually or together.

In that system, the user is able to directly paint regions of interest on the 2D slices and view them in the 3D view, allowing the user to

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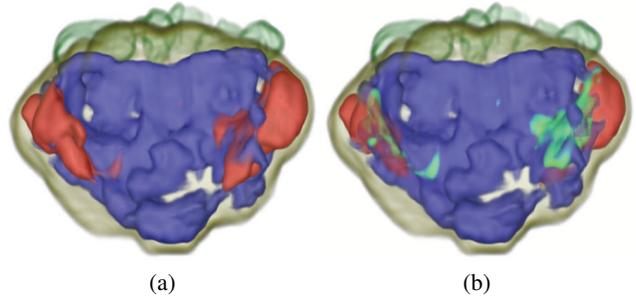


Figure 1: Examples of prostate rendering with score volumes. (a) Normal rendering of isosurfaces with T_2 -weighted score in blue and T_1 -weighted score in red. (b) Original persistence visibility rendering, with T_2 persistent over T_1 and tinted green when they overlap.

identify their own regions instead of relying purely on computer-aided detection (CAD) schemes. A method was introduced, referred to as *visibility persistence*, which would allow two different scores to be viewed at the same time, with a persistent score always remaining visible. If the persistent score was occluded, the other score in front would be rendered transparently so that the occluded score could be seen. If the two scores overlap, a distinctive color (green) was used to tint the region to indicate an overlap.

Although this works for the basic scores with predefined colors, the user is able to choose any custom color to use in painting custom regions. This allows different colors to be used for different purposes. However, this does not allow for a simple tinting procedure, which requires a predetermined color palette. In this work, we seek to present to the user occluded and overlapped custom painted regions combined with the score data.

2 VISUALIZATION DESIGN

In the original system, the method of visibility persistence was developed to allow two scores (e.g., T_2 -weighted and T_1 -weighted) to be viewed at the same time, while maintaining visibility of one of the scores. This persistent score would always remain visible, even when occluded by the other score. Also, overlaps would be indicated by using a distinctive tinting color. Since blue was used to represent T_2 -weighted scores and red was used to represent T_1 -weighted scores, the logical choice for the tinting color was green. The surface of the prostate and the seminal vesicles are always rendered as semi-transparent tan and green isosurfaces, respectively.

The previous method worked by using a modified compositing strategy. A second volume rendering integral is accumulated with reduced color and opacity values for the non-persistent data (in this case, the T_1 or T_2 scores). A tinting function would determine if the persistent data would be colored based on the values of the non-persistent data. A final blending between the two rendering integrals was then performed to display the correct result, modulated by the accumulated alpha of just the persistent data. This would allow for normal isosurface rendering in regions that do not contain the persistent data, while regions containing the data would have non-persistent data show as transparent, allowing the persistent surface to be seen. An example of this method is shown in Figure 1.

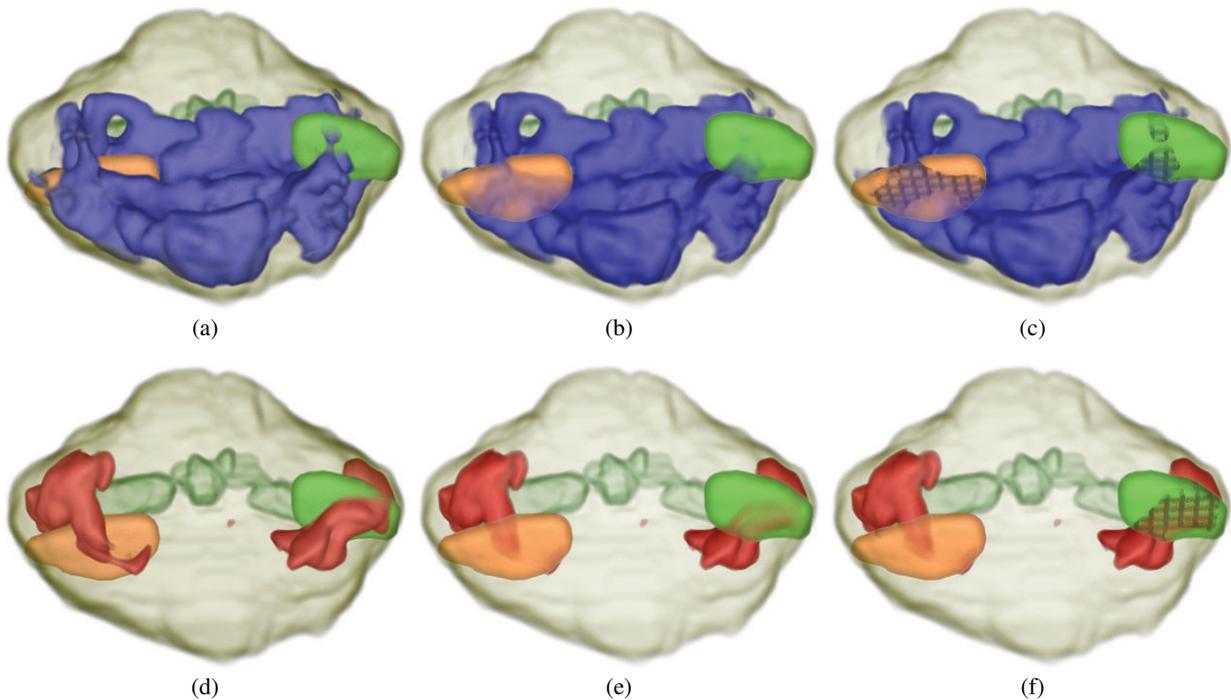


Figure 2: Examples of new persistence visibility for custom painted regions. T_2 scores are rendered in blue, T_1 scores in red, and two custom regions are present in orange and green. (a) and (d) show normal isosurface rendering. (b) and (e) show visibility persistence with no overlap indications. (c) and (f) show visibility persistence with overlap indications as striped patterns. In (e), for example, it can be seen how it might be ambivalent as to whether or not the painted orange and green regions are inside of the T_1 score data when simply revealing occluded structures. However, in (f), it can be clearly seen that the green region does overlap with portions of the T_1 score data, while the orange region does not.

While this works well for such a closed system with predetermined colors, it does not translate well to the open system of allowing the user to paint custom regions within the prostate. In such a case, this default tinting of the custom painted regions is not applicable, as the user can choose any color to paint the regions in. While it would be possible to restrict the user’s choice of colors, this was not deemed a prudent course of action.

For general occlusions, the same technique is used so that structures in front of the painted regions will appear with reduced opacity, allowing the painted region to be visible. For regions of overlap, it was decided to place a striped pattern on the painted region to indicate the overlap. Since this is not color dependent, the user is free to choose any colors for the painted regions (which do not conflict with the default T_2 and T_1 score colors). The presence of this striped pattern is based on the alpha value of the T_1 and T_2 scores at the sampling location. The stripes are created by halving the RGB color values for the painted region, which results in more of the overlapping color being present. The striped pattern itself is determined by the sample position within the 3D volume, so the pattern remains consistent from varying viewpoints. Examples of this updated method are shown in Figure 2.

The volumetric ray casting is performed entirely on the GPU using an NVIDIA GeForce GTX 480. Because of the requirement of maintaining visibility of occluded regions, early ray termination cannot be applied to the general score data since a painted region might be hidden behind it. However, interactive performance remains throughout use with a 512×512 render target.

3 CONCLUSION

We have presented here a method for displaying overlapping regions of interest with indications for where these regions overlap as opposed to simply occlude each other. This has been developed in conjunction with a prostate MRI visualization system and was cre-

ated to allow the user to maintain visibility of custom regions that they painted when viewing in combination with CAD data. The method is intuitive and maintains interactive performance when using GPU-accelerated ray casting.

We are further exploring methods of indicating which score overlaps with a painted region. We are also looking into the possibility of indicating where the overlaps occur while only rendering the painted regions, in order to reduce visual clutter. For these, we are seeking user feedback for the system. We are also investigating methods for speed enhancement for the ray casting procedure.

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