Realistic visualization of DTI tractography of healthy and ischemic hearts

Poster No.:	C-193
Congress:	ECR 2009
Type:	Scientific Exhibit
Topic:	Cardiac
Authors:	T. H. J. M. Peeters, A. Vilanova, G. J. Strijkers, B. M. ter Haar Romeny; Eindhoven/NL
Keywords:	diffusion tensor imaging, Heart, ischemia, Visualization
DOI:	10.1594/ecr2009/C-193

Purpose

The heart consists of densely packed muscle fibers. The orientation of these fibers can be acquired by using Diffusion Tensor Imaging (DTI) ex-vivo. A common way to visualize the fiber structure in across section of the heart is by color coding the fiber orientation represented by, for example, the *helix angle*. This is illustrated in figure 1.

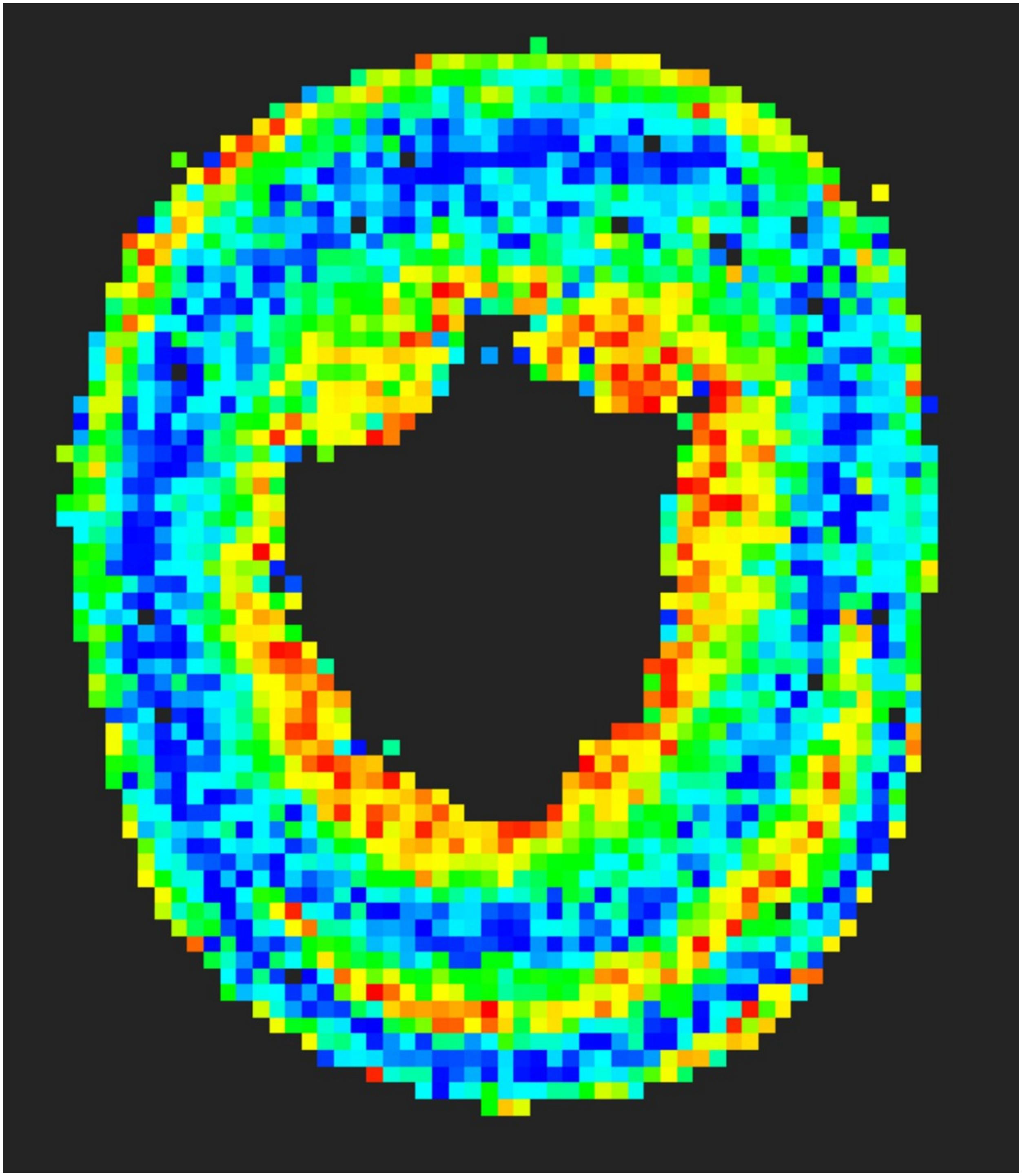

Fig.: Color coding of helix angle. Blue indicates in-plane fibers, red is out-of-plane.
A recently introduced good way to visualize the fiber structure in a cross section of the heart is by showing short line segments originating from the cross section and aligned with the localdirection of the fibers, as is shown in figure 2.

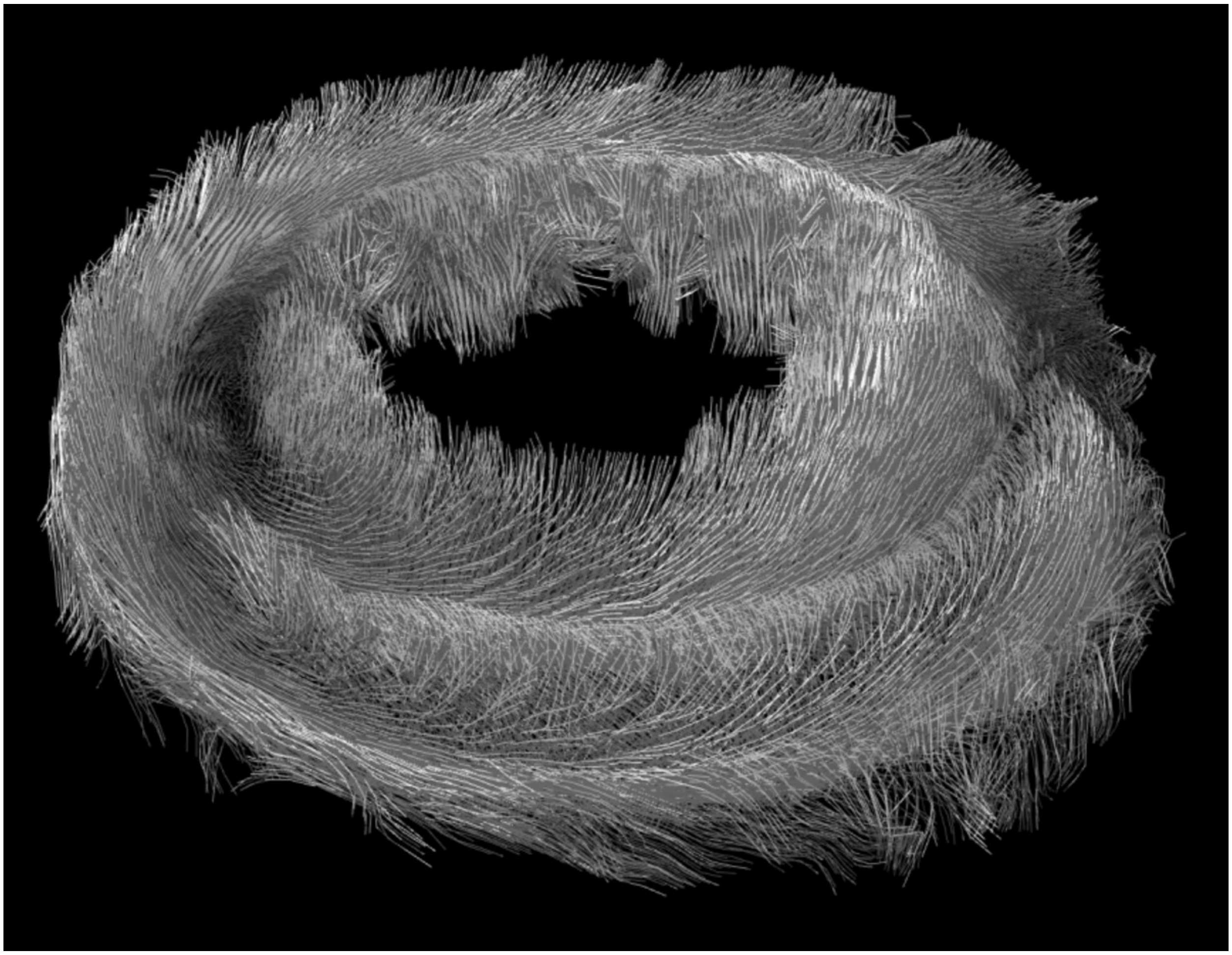

Fig.: Rendering of tracked fibers in an axial slice of a healthy mouse heart which was scanned ex-vivo. Line lighting is used to show the fiber shapes. It is supplemented with rendering of shadows to enhance the perception of coherent structures among fibers.
If the line segments are placed dense enough, one can see how the fiber orientations change. However, generation of the line segments takes time and thus the user has to wait for new geometry to begenerated when the plane defining the cross section is changed. We present a new direct rendering method for the visualization of the 3D vector field in a 2D user-definable cross section of the heartthat does not require any preprocessing such as the generation of line segments.

Methods and Materials

Our goal is to render a dense set of simple glyphs (i.e. line segments) that originate from a user-specified cross section defined by a plane-of-interest (POI). The seed points that are used as theorigins for the line segments are implicitly defined by the POI and a user-specified seed-distance. We do not do any rendering calculations on the CPU. First, the whole vector volume is loaded intothe GPU memory as a 3D texture and we pass the parameters of the POI to the GPU. On the intersection of the plane with the vector field, the full 3D vectors are rendered as 3D line segments with alocal ray casting approach. No preprocessing of the data is needed and no geometry is generated. This technique allows a fast inspection of the data to identify interesting areas where furtheranalysis is necessary (e.g., quantification or generation of streamlines). We also show how the technique is generalized to other glyph shapes than line segments by implementing ellipsoids.

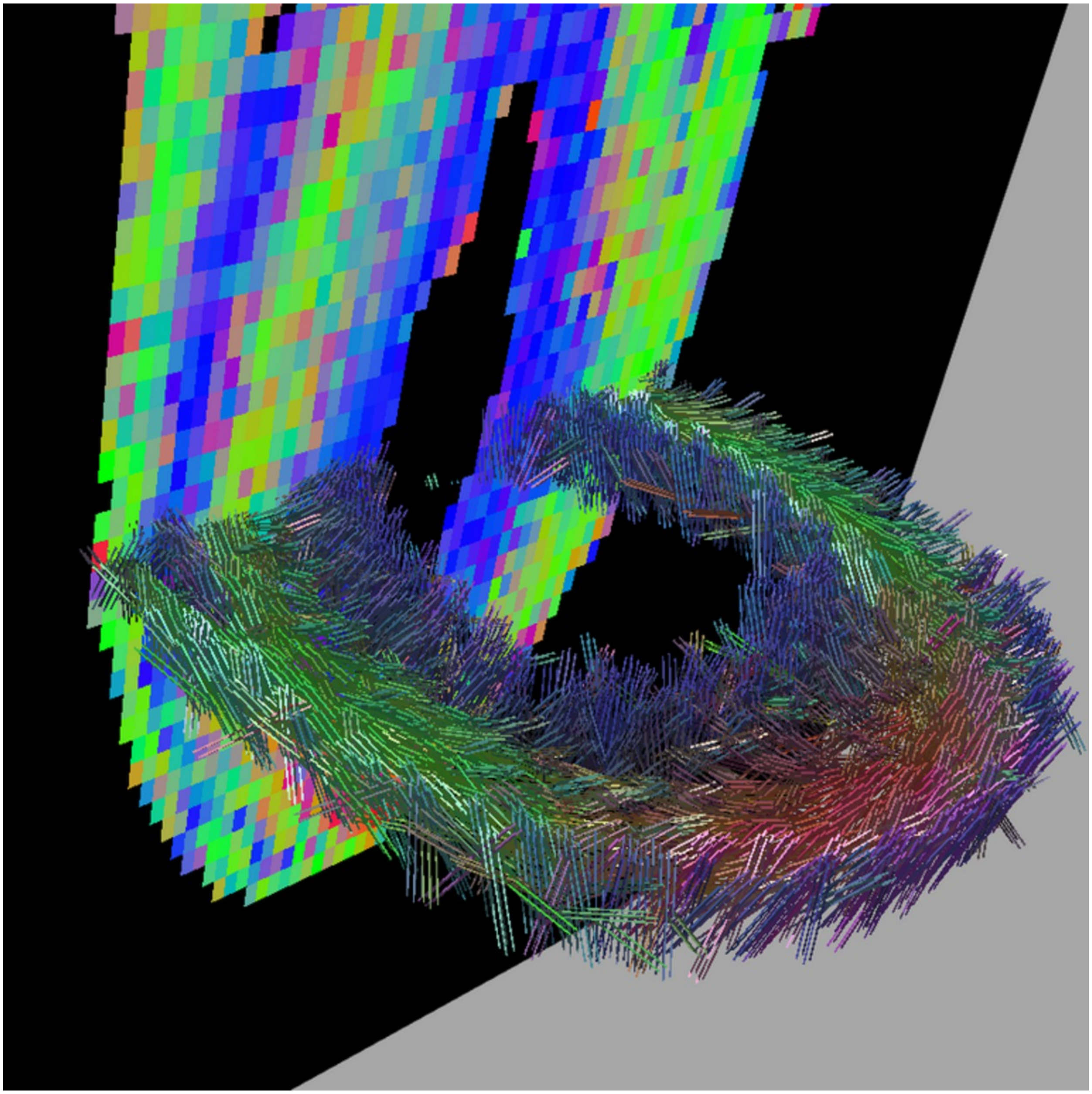

Fig.: Our new rendering method showing an axial cross section of a healthy mouse heart. RGB coloring of fiber orientation was applied to the fibers and to the textured planeshowing a coronal cross section in the background.

Results

We applied the proposed visualization to a series of healthy and infarcted mouse hearts. Four datasets were available of healthy hearts. For infarcted hearts we had 5, 4 and 5 datasets measuredrespectively at 7, 14 and 28 days after infarction. The results of the proposed method look the same as the method that generates geometry. To illustrate this, figure 4 shows a cross section usinggeometry, as well as a cross section rendered using our new method.

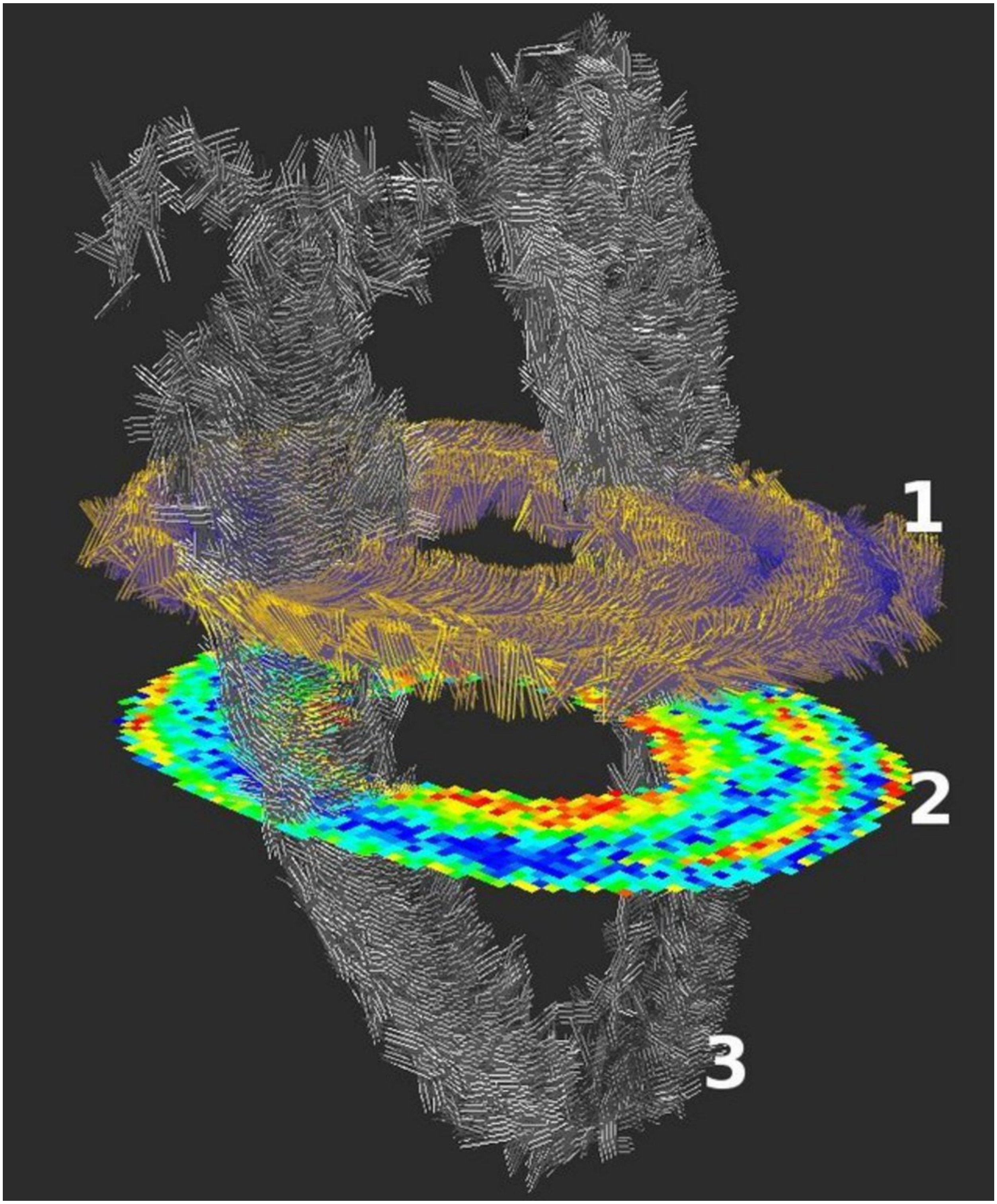

Fig.: Three cross sections of a healthy mouse heart visualized with three different methods. (1) Short line segments rendered as geometry. (2) Color-coding of helix angle shown as a texture on a plane. (3) Short line segments rendered with our new method.

The topmost short-axis cross ssection (1) uses short line segments that were rendered as geometry. The bottom short-axis slice (2) shows fiber orientations as colors using

helix angle coloring. Thethird slice (3) was placed freely using our interactive POI and is close to a long-axis cross section. It was rendered using our proposed method.
In order to distinguish the two methods for renderingline segments, we applied tone shading to the geometrybased rendering to give it a different color. The seeding distance and fiber length was the same for both methods.
Performance measurements

Method	dataset	Number of seeds	Generate geometry (s)	Render performance (FPS)
ray cast lines	mouseheart	10K	-	35-50
geometry lines	mouseheart	10K	5	28-30
ray cast lines	mouseheart	27K	-	30-40
geometry lines	mouseheart	27K	14	25-28
ray cast ellipse	infarcted	8K	-	20-35
geometry ellipse	infarcted	8K	10	10-12

When comparing a previous, geometry based, rendering method with our proposed method, it can be seen that the different approaches are competitive when it comes to rendering performance. However, ifthe user wants to to change the POI or properties of the lines or ellipsoids that are being rendered, then new geometry needs to be generated which currently takes a waiting time in the order ofseconds. With our proposed ray casting method, this step is not needed so we clearly outperform geometry-based methods there.

Conclusion

Our main contribution is a new GPU-based ray casting technique for interactively visualizing cross sections of the heart, which consists of densely-packed muscle fibers. This cross section can bechosen interactively by the user by moving and rotating a plane-of-interst (POI). In the POI, the full 3D fiber orientations are visualized as short lines or ellipsoids, using proper lighting andshadowing. This enables the user to quickly inspect a volume of vectors derived from a DTI scan of mouse hearts. For this application, it is very important that the seeding is very dense in order toshow the gradual change in fiber orientation througout the heart wall. It is also important that the user can interactively place the POI. The proposed method outperforms the approach where geometryis generated, and can be used for fast inspection of the data to identify interesting areas where further analysis is necessary. It can be used, for example, to select areas where quantification(e.g., statistics of fiber orientation or FA in healthy vs. infarcted areas) is done or where to place seed points to initiate fiber tracking. An additional advantage of our technique is that itallows interactive changes in parameters, such as seeding density and line-segment length, without the need to generate geometry.