User Interfaces to Interact with Tensor Fields

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Abstract Nowadays there is a growing interest in tensor medical imaging modalities. In Diffusion Tensor Magnetic Resonance Imaging (DT-MRI), each pixel is valued with a symmetric second-order tensor describing the spatial properties of diffusion at that point. Therefore, it provides significantly more information than scalar modalities, but this causes the complexity of the interfaces dealing with them to grow. In this chapter, the current situation of user interfaces for tensor fields is reviewed. Tensor user interfaces are difficult to design, given the difficulty of mentally integrating data with so many parameters. This is why a considerable effort must be invested in order to achieve intuitive and easy-to-use interfaces. The display of tensor information plays an important role in this, and we review several existing visualization methods for tensor fields. We must point out that, although most of the applications are graphical interfaces, there are also examples of command-line tools and multimodal interfaces employing virtual environments. We study some of the current medical user interfaces for diffusion tensor fields.

1 Introduction

Medical imaging has proven to be an invaluable tool for physicians. Among the existing modalities, Magnetic Resonance Imaging (MRI) obtains good quality images without exposure to ionizing radiation, measuring instead the response of hydrogen atoms to strong magnetic fields. Diffusion Tensor MRI (DT-MRI) is an imaging method that measures the water diffusivity in different space directions and models it as a second-order tensor. Therefore, this modality detects information about the internal structure of a tissue that other techniques cannot uncover [3]. For example, it can detect the fibrous structure of white matter, which is seen by other imaging modalities as an homogeneous tissue. Neurology and neurosurgery can greatly ben-

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efit from DT-MRI, as it allows the *in vivo* computation of tractographies, the pathways of the nervous fibers. Some medical applications where diffusion tensor imaging plays an important role are [42]: research on multiple sclerosis [27], leucoaraiosis, cerebral ischemia, diffuse axonal injury, image-guided neurosurgery [43], neurooncology, white matter abnormalities in schizophrenia [36], epilepsy, etc.

However, due to the complexity of this imaging modality, images must be processed before meaningful information can be extracted from them. It is then fundamental to develop user interfaces for DT-MRI, in order to profit from the advantages offered by this modality. Additionaly, they should use visualization methods that represent the information given by the tensors at each point of the image in an intuitive way for the user. This is not an easy task, and some research has been conducted in the last years to accomplish this goal.

There are not too many software applications for DT-MRI, but they are growing in number, and they can be classified into command-line tools, graphical user interface (GUI) applications, and multimodal interfaces. In addition, as most of these interfaces are fairly recent, they are evolving, improving their usability or adding new functionalities to the already existing ones.

The rest of the chapter is organized as follows. Firstly, some concepts about diffusion tensors and DT-MRI are explained in Section 2. Then, an overview of the existing visualization techniques for tensor fields is given in Section 3, as they are an important part for most user interfaces. Next, the command-line tools, GUIs and multimodal interfaces are respectively reviewed in Sections 4, 5 and 6. They are followed by a discussion in Section 7, and some conclusions in Section 8.

2 Diffusion Tensor MRI

The design of user interfaces for diffusion tensor imaging requires at least some knowledge of tensor theory, especially in order to understand the visualization techniques of this kind of data.

Diffusion is a property of a physical medium that measures the Brownian motion of the molecules present in it. When the medium is isotropic, only a scalar is needed in order to characterize diffusion completely. When it is anisotropic, however, the diffusion depends on the direction along which we are measuring it. This is why a symmetric tensor is needed to characterize diffusion in this case [3, 32]. We will refer to such a tensor as $D = D_{ij}$, where $ij = 1,2,3$. It must be noted that lower indices will be used in spite of them being contravariant. This is done for clarity of notation. In matrix form, the diffusion tensor is usually represented as:

$$D = \begin{pmatrix} D_{11} & D_{12} & D_{13} \\ D_{21} & D_{22} & D_{23} \\ D_{31} & D_{32} & D_{33} \end{pmatrix} \quad (1)$$

DT-MRI is a method for measuring the relative diffusion coefficients of water molecules in different directions of an image [32], using magnetic resonance imag-