UNBOXING

Diffusion Tensor Imaging

A quick guide for beginner researchers

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Diffusion Tensor Imaging Unboxing

A quick guide for beginner researchers

Antonio Senra Filho

This book is for sale at http://leanpub.com/dtiunboxing-en

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to my wife Karolyne

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1: Introduction

Advances made over decades of research and production technology, particularly focusing on biomedical applications, have led us to new and better ways of visualizing the human body, providing valuable information about the structure and function of various tissues and organs. Among the imaging modalities most used today, the technique known as Nuclear Magnetic Resonance Imaging (NMRI or just MRI) is a particularly powerful imaging technique that has revolutionized the field of diagnostic imaging in medicine. . One of the main reasons for this is the high capacity for differentiating tissues and organs, offering high-resolution images without the use of ionizing radiation. Therefore, improving the diagnostic potential with a very low risk to human health.

The physical principle that makes up the MRI exam also allows for a wide diversity of imaging modalities, offering physical-biological knowledge that is very important for other complementary interpretations about the human body and how diseases can manifest themselves in biological tissue. Considering several types of images possible to be formed on the MRI tomograph, one of the main modalities that is constantly being improved and studied is the well-known diffusion-weighted image, which provides information about the movement of water molecules within the human body in a non-invasive way. and with high spatial detail. This technique is particularly useful for studying the structure of the brain and nervous system, as well as other soft tissues.

The diffusion weighted imaging technique, also known as Diffusion Weighted Image (DWI), can be expanded to another modality also based on diffusion, known as Diffusion Tensor Imaging (DTI). Both forms of imaging are powerful tools for analyzing the microstructural organization of tissues. However, currently, the DTI technique has gained a lot of attention due to its three-dimensional potential for describing the human body with a focus on the structuring of biological tissue. Many applications have already been made in diagnostic complementation for various diseases and studies of the central nervous system. However, despite its broad application potential, DTI imaging still presents a first knowledge barrier as it deals

with physical concepts that are difficult to understand and interpret, especially for those who are new to this field of study. In this sense, I saw the need to create this simplified and accessible guide that could help people who are coming into contact with this type of biomedical imaging.

1.1: Quick review on DTI images

The diffusion-weighted magnetic resonance imaging technique (DW-MRI, or simply DWI) is a very powerful biomedical imaging modality as it is capable of providing structural information about the human body, using the principle of movement of water molecules within the fabrics. Diffusion movement is natural in any material in nature, its intensity being proportional to the degree of freedom that the physical structure of the matter allows. In other words, gaseous media offer freer movement for molecules when compared to solid media. It is on this principle that we support the reasoning behind DWI imaging, which is aimed at studying the movement of water molecules in the human body. By studying water diffusion, it is possible to reveal important structural and functional information about the brain, nervous system and other tissues. An extension of the DWI imaging principle is the adoption of three-dimensional mapping of water, making it even more interesting to study the behavior of diffusion displacement in all directions, providing a more reliable interpretation of what happens in the natural environment of the human body. This more comprehensive diffusion technique is called Diffusion Tensor Imaging (DTI).

DTI imaging is based on the principle of diffusion anisotropy, that is, the fact that considering different tissue organizations it is possible to obtain a greater or lesser barrier for water displacement. Thus, water molecules can diffuse more easily in some directions than others, offering a broader understanding of how biological structure is organized. Therefore, we can take it as a natural principle that there is the presence of obstacles in the biological environment, such as cell membranes or the axonal structure itself in the cerebral white matter, which restrict the movement of water. By knowing how MRI imaging can be influenced by directed magnetic field gradients, it is possible to obtain the MRI signal decay contribution from diffusion motion. However, this principle will be elucidated in greater detail in later chapters.

The potential of DTI imaging translates into the ability to obtain tissue orientation and microstructural organization, which is not easily achieved with other MRI

imaging modalities, such as T1 or T2 weighted images. An image reconstruction that comes from calculations based on the DTI image sequence and that is widely applied today are fractional anisotropy (Fractional Anisotropy - FA) and mean diffusivity (MD) maps, which reflect the degree of anisotropy in tissue diffusion. Higher FA values indicate greater anisotropy and more structured tissue organization, while lower values indicate greater isotropic diffusion and less structured tissue organization. The opposite is applied to MD maps, that is, high MD values indicate a high level of water diffusion, while low MD values indicate greater restriction of water movement at the location.

DTI imaging has a number of advantages over other imaging techniques. Among them we can mention its non-invasive ability to study the human body, the high spatial resolution considering the macroscopic interpretation of water diffusion and also the ability to reveal important structural and functional information about tissues without the application of ionizing radiation. Even though most of the applications that use DTI images are aimed at studying the human central nervous system, we can also find other possibilities for use in studies such as pediatrics, orthopedics and other parts of the human body. Without a doubt, there is still a lot that can be done with this versatile imaging modality.

1.2: Structure and objective of the book

The objective of this book is to provide a comprehensive overview of diffusion tensor magnetic resonance imaging (DTI), from the fundamentals of image formation to its forms of reconstruction and analysis. I will approach the topic in a simplified way, aiming whenever possible to offer a broader interpretation so that as many people as possible can begin their studies in this imaging modality. In addition to making an initial review of the physical part and its imaging principle, I will also seek to discuss the most frequent and consolidated applications of DTI today, as well as future trends in the field of medical research and clinical practice.

The book is structured to allow readers to gradually develop their understanding of DTI imaging, starting with the basics and moving on to more advanced topics. The first few chapters provide a review of DTI imaging, considering the basic physical principle of diffusion and how the MRI scanner is capable of capturing this type of signal. Further, we focus on the possible applications of this imaging

technique, considering the specific view of current clinical routine and also the research projections considered at the time of writing this book. The final chapters of the book are more focused on the study of analysis tools and techniques that are more recently applied, aiming to prepare the reader for the processing of this type of technical data, which usually recruits knowledge of biomedical image processing as reading and image transformation into DICOM format, pre-processing and artifact removal and reconstruction of the main quantitative image modalities such as FA, MD and other types.

It is worth mentioning that I do my best to keep citations from books, scientific articles and other materials that are relevant for the reader to understand the best possible about DTI images and how to continue with more in-depth studies. Again, I do not intend to write extensively about DTI, as there is a lot of excellent quality material present in the literature. My main objective here is to facilitate your study journey in the face of this large amount of information and also to try to facilitate the initial interpretation of this type of image which presents, at least for people with little contact, a level of complexity that can be a barrier to continue the study further.

2: Technical review on DTI

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2.1: Basic principles of diffusion in MRI

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2.2: Diffusion-weighted imaging

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2.3: Expanding the representation for the diffusion tensor

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2.4: References

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3: DTI analytics and applications

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3.1: Advantages and limitations of diffusion-weighted imaging

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4.4.1: Tract-Specific Analysis (TSA)

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4.5: References

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5: Final thoughts and recommendations for future studies

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5.1: Key Points to Consider

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