Universidad de Valladolid

OVERVIEW

MICCAI 2022 Challenge: QuaD22

Quality augmentation in diffusion MRI for clinical studies: Validation in migraine

MAIN QUESTIONS

- Are Deep Learning (DL) Techniques able to improve the quality of diffusion MRI data to be used in clinical studies?
- Are the subtle details and differences between groups kept or lost when using DL?
- Which specific DL method is more suitable to be used in dMRI clinical studies?

OVERVIEW

In this challenge, we ask the participant to upgrade diffusion MRI data acquired with only 21 gradient directions to 61 gradient directions via DL. As a final result, we will ask them to provide only three scalar metrics: FA, MD and AD. In order to compare the different methods, we will use a real clinical study in which we statistically compare episodic migraine to chronic migraine. We have detected that differences between groups disappear when using 21 directions instead of 61. Will any DL method be able to recover those differences?

MOTIVATION

Deep Learning (DL) techniques have been used in medical imaging to improve quality and generate new images from reduced medical imaging acquisitions. They have implied a true revolution in the medical field, with myriads of new applications rising every year. We cannot deny the excellent outcomes these applications produce, with high-quality images and compelling results. However, when applied to medical images, most of the validation of these techniques has been done visually and/or qualitatively, not necessarily adequately assessed in clinical studies. There is a key question that may affect many of the DL applications in medical studies:

"Are we losing relevant quantitative clinical information when generating high-quality images with artificial intelligence techniques?"

The question is related to the validity of traditional quality measures such as the Peak Signal-to-Noise Ratio (PSNR), Structural Similarity Index (SSIM) or Normalized Root Mean Squared Error (NRMSE), commonly used in medical image analysis. Strictly speaking, it is not enough that the images look alike as they must also preserve all the relevant clinical information.

In this challenge, we will try to answer the question about the validity of reconstructed images in a real clinical study. To that end, we will focus on a real diffusion magnetic resonance imaging (dMRI) study on migraine. Data were acquired for a clinical study carried out in a local hospital (Hospital Clinico Universitario, Valladolid, Spain) by a group of neurologists.

We have selected migraine considering that it is a pathology in which differences between groups are subtle and very dependent on the number of gradient directions.

TASKS, DATA AND DESCRIPTION

1.-Description:

The angular resolution (i.e. the parameter that is proportional to the reciprocal number of diffusion gradient directions) is one of the crucial design parameters used in a diffusion MRI experiment. Depending on the method employed to represent the diffusion MRI signal, a different number of gradient directions are required to fit the basis starting from six gradients in diffusion tensor imaging (DTI) to several dozens or hundreds in High Angular Resolution Diffusion Imaging (HARDI) techniques. In clinical studies, we are generally interested in optimizing the number of gradient directions to limit the acquisition duration and guarantee the patient's comfort during the examination. However, reducing the number of gradient directions may lead to a loss of subtle changes in angular characteristics of diffusion MRI data, which translates then to quantitative measures retrieved from a fitted model.

Recent studies have suggested that decreasing the number of gradients leads to clinical information loss, and it becomes impossible to detect differences in various types of medical conditions. A reported key factor influencing the values of diffusion/DTI descriptors is the number of diffusion gradient orientations, which (may) impact the results of their statistical comparison between clinical groups.

2.-About the Selected Pathology:

Migraine is a primary disabling disorder characterized by recurrent episodes of headache that usually last 4-72 hours. It is more widespread among young and middle-aged women. Despite the high prevalence of migraine, its pathophysiological mechanisms are not well known, and there are no biomarkers currently. Two types of migraine are currently distinguished: episodic migraine (EM) and chronic migraine (CM). This classification criterion is based exclusively on the number of headache

days per month (15 or more days with headache per month for chronic migraine patients). The unique, relevant radiological findings in migraine are white matter hyperintensities observed through T2-weighted images, and their role is unclear. The advantage of migraine in a challenge like the present one is that MRI findings related to diffusion MRI are subtle compared to healthy controls, according to previous studies. In severe disorders such as Alzheimer's disease or schizophrenia, it is relatively easy to find statistically significant results with classic methods (i.e. DTI, T1-, T2-weighted MR imaging), and thus it is challenging to appreciate techniques or parameters that can better define pathophysiological properties. There are some diffusion MRI studies assessing migraine. DTI has been the most employed technique to evaluate microstructural properties with differences found between controls and migraine patients and between EM and CM patients for DTI-related scalars like fractional anisotropy (FA), mean diffusion (MD) and Axial Diffusivity (AD).

3.-Data:

For the challenge, we will share two datasets:

1. Training dataset: A fully-sampled diffusion-weighted MRI dataset acquired with 61 gradient directions at b=1000 s/mm^2 coming from 60 healthy controls. The sampling scheme allows the 61 gradient directions to be easily subsampled to 21 gradients.
2. Migraine dataset: A set of 50 Chronic migraine (CM) and 50 episodic migraine (EM) patients, all acquired in a subsampled scenario with 21 gradient directions and b=1000 s/mm^2.

4.-Task:

Participants are expected to estimate three DTI-based parameters (FA, MD and AD) from the migraine dataset acquired with 21 diffusion gradient directions at b=1000 s/mm^2, but with a quality similar to the parameters estimated from 61 gradient directions. To that end:

1. They can use the training data set to angularly augment the diffusion MRI data from 21 to 61 gradient directions to provide the most faithful representation of the signal and consequently the quantitative parameters, including FA, MD and AD. Deep Learning methods are recommended here.
2. Then, they will apply the method to the migraine dataset. The participants will submit three volumes (FA, MD, AD) for the 50 EM and the 50 CM subjects.

5.-Evaluation:

Organizers have the migraine dataset acquired with 61 gradient directions. A clinical study (statistical test) has been carried out to find the differences between EM and CM, with the following result:

- There are many significant differences when using 61 gradient directions.
- Most of the differences disappear when using 21 gradient directions.

Differences found with 61 gradient directions will be considered the *Golden Standard.* A new statistical test will be carried out with each set of volumes submitted by the participants. Results will be compared with the golden standard.

ADDITIONAL INFORMATION

Important dates:

Release of training data (healthy controls):	April 1, 2022
Release of challenge data (patients):	June 1, 2022
Team registration deadline:	June 1, 2022
Final submissions:	July 15, 2022

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