MSc project – Super-Resolution Brain Magnetic Resonance Imaging

The problem

High-resolution medical images are desirable for accurate disease diagnosis and image-guided therapy. Magnetic resonance imaging (MRI) is an extensively used clinical imaging technique. Due to its relatively long scan time (multiple min per scan), the spatial resolution of MRI is limited. Furthermore, the longer the scan time, the more sensitive it becomes to patient motion, which may create unacceptable motion artefacts in the images.

Current practices/research

Some conventional (polynomial interpolation, sparse-coding) and an emerging deep learning techniques are used to predict high-resolution data from low-resolution data. Deep learning came out to be a promising approach and has a great potential for preclinical and clinical imaging. Deep learning based methods extracts the prior information from large training data and thus can produce superior MRI images from a low-resolution counterpart.

For super-resolution MRI, there are some early attempts with a standard 3D convolutional neural network (CNN), generative adversarial network (GAN), and a combination of both. Many researchers in the field have tackled this as a reconstruction, de-noising or a de-blurring problem and came up with the relevant networks. Little attempts have been made for filling in the true missing high-frequency details.

The desired solution

A deep learning based solution is needed to reconstruct high-resolution 3D brain MRI from low-resolution 3D brain MRI, which can be acquired at a relatively low scan time. A network is desired to learn the missing details (higher spatial frequencies) from the low-resolution MRI data and its high-resolution counterpart. An example of such data is shown in Figure 1.

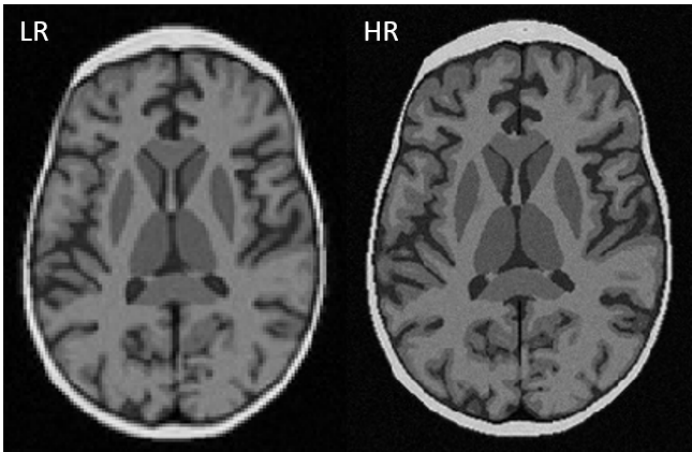

Figure 1: An axial slice of Low Resolution (LR) and High Resolution (HR) simulated brain MRI. Images generated are of 2 fold multi-resolution, where LR being generated at 1.4mm cubic and HR at 0.7mm cubic. The goal is to use multi-resolution data to train a network that can learn the missing high frequency details in LR data and can predict HR data from LR data. Data shown was simulated with the physical MRI simulator JEMRIS.

The MSc project

The goal of this MSc project is to develop and evaluate a deep learning super-resolution networks for 3D brain MR images, which can predict the missing details and can produce sharp and more complete high-resolution counterparts. The project will consist of the following steps.

Datasets: Real high-resolution 3D T1w or T2w brain MR images can be taken as high-resolution (HR) labels. Desired low-resolution (LR) counterparts can be made either by:

1. Down sampling in image domain
2. Cropping in the frequency domain, by going back and forth in image and frequency domain using Fourier transform
3. Acquisition of true low resolution counterpart

On the other hand, the paired data (e.g. up to 2 fold multi-resolution) generated by means of physics based simulations and image derived synthesis can be used as well. Such data will come along with raw k-space (large sets of generated 3D brain MR image data will be provided by the ongoing OpenGTN project). Moreover, a mix and match of all real and generated data can be used for training and testing purposes.

Image/k-space based learning: A standard image based, a k-space based, or a combination network has to be explored and trained for 3D brain MRI super-resolution.

K-space pattern learning: For prediction of missing details, an optimum k-space pattern has to be learned. Based on which, selection of frequency components is to be made. So the LR images should include those selected frequency components, and a better prediction can be made.

CNNs/GANs based approach: Off the shelf CNNs and GANs should be explored for given super-resolution problem in 3D brain MRI. Then should be optimized for given real and/or generated data to find out which approach and individual network settings results best in filling the missing details.

Image evaluations: The overall image quality, edge sharpness, presence of high frequency details, and a possible noise suppression have to be evaluated quantitatively and qualitatively of predicted HR images. The quantitative evaluations will be performed on images not used during optimization of the network. Before the start of the evaluation, a proper study design needs to be formulated. The visual qualitative evaluations will be performed with the expert help.

Reporting: A final report will be written in the form of a scientific article, using the IEEE scientific journal template. Potentially, an abstract about the performed research can be submitted to a scientific conference, and an adapted version of the final report can later on be offered for publication to a scientific journal.

Final presentation & defense: The MSc project is concluded with a 25-min presentation and a 45-min defense session.

Expected skills and experience

- Programming in Python, other languages (e.g. course BMB502417)
- Machine learning / deep learning (e.g. courses 8DM40, 8DM00)
- Medical image analysis (e.g. courses 8DC00, 2DMM10)
- Experimental study design (course 8DM20)
- Written and oral communication in English

Contact

Are you interest in this project? Do you want more information?

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