CREATIS

SIEMENS Healthineers

MRI multi-contrast super-resolution reconstruction using variational approaches: application to cancer diagnosis

Industrial PhD. (CIFRE)

Starting October 2022

Methodological objectives

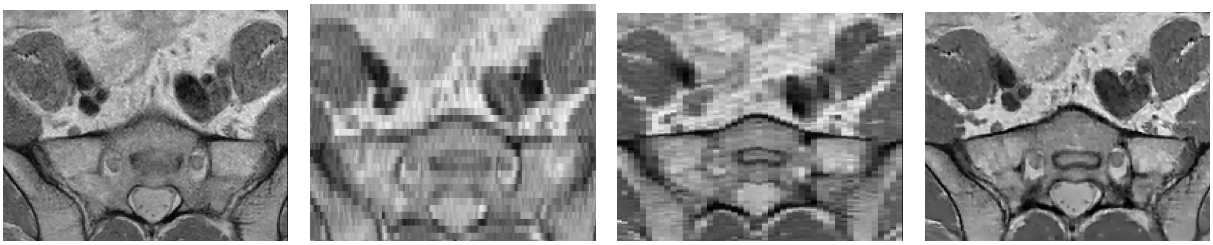
MR imaging generally imposes a compromise between acquisition time, signal-to-noise (SNR) ratio, and spatial resolution. Super-resolution (SR) is a post-processing methodology that is able to reconstruct high spatial resolution images with high SNR from a set of low resolution images usually acquired orthogonal to each other [3].

One way to tackle the SR problem is to solve an inverse problem using variational approaches. They aim at minimizing a cost function, usually composed of a data fidelity and a regularization term:

$$\mathcal{C}(X) = \sum_{k=1}^{N} \|Y_k - H_k X\|^2 + \lambda R(X) \tag{1}$$

Minimizing $\mathcal{C}(X)$ consists in finding the high resolution image X that minimizes both the mean square error with respect to the N low resolution images Y_k, and the regularization term $R(X)$. Operator H, which cannot be inverted, operates the transition from the high resolution to the low resolution spaces. It regroups the operators related to sub-sampling, point-spread-function (PSF), and acquisition geometry. The SR problem as stated in Eq. 1, requires that all low resolution images have similar intensity distributions, i.e. that they are acquired with similar contrasts, producing in turn a high resolution image with the same contrast (see Figure 1).

One of the main objective of this PhD. is to relax the constraint on contrast homogeneity in order to



(a) Axial acq. (b) Coronal acq. (axial reconstruction) (c) Sagittal acq. (axial reconstruction) (d) SR reconstruction

Figure 1 – An example of SR reconstruction on MRI spine images

reconstruct high resolution images from multi-contrast low resolution acquisitions. This implies fundamental changes on the cost function and the reconstruction process, since the data fidelity term becomes irrelevant. Part of these developments will focus on specific regularization terms recently investigated in [2], which are able to adapt the image a priori based on an edge map iteratively formed during the reconstruction process. The relationship with recent developments in compressive sensing will also be investigated [4], because of their ability to reconstruct high quality images from various contrasts [1].

Clinical objectives

This PhD. will be carried out in close collaboration with Pr. Frank Pilleul, head of the radiology department at the CLB (Centre Léon Bérard). The CLB is dedicated to cancer care and hosts research activities in partnership with academic institutes including CREATIS. Two clinical Siemens MRI systems (1.5T Prisma and 3T Vida), are available at the CLB for cancer diagnosis, research purpose and methodological developments (including the ones carried out during this PhD.).

Clinical imaging protocols usually consist in the acquisition of several multi-slice 2D or 3D images, with specific clinically relevant contrasts and/or orientation. In some applications such as abdominal or pelvis imaging, the duration of single acquisitions is restricted by patient and/or physiological motion (e.g. breathing, cardiac). In this context, scan duration is reduced with degraded spatial resolution, especially in the slice dimension leading to the acquisition of highly anisotropic voxels affected by severe partial volume effect. In order to accurately represent the 3D anatomy and obtain clinically relevant contrasts, multiple 2D acquisitions with different orientations are preferred to 3D acquisitions for their better contrast and robustness to motion, but result in longer scan protocols.
This PhD. will investigate to which extent SR algorithms are able to:

- accelerate imaging protocols by producing, as a post-processing step, high resolution images with satisfying contrasts and SNR, which might either suppress the need for the acquisition of high resolution images, or allow to reduce the spatial resolution and/or SNR of the acquired images.
- improve the diagnosis accuracy by producing several high resolution images with different contrasts by combining low resolution images acquired with different contrasts

Methodological developments will be applied on the pelvis protocol used at CLB, that currently includes the acquisition of three orthogonal images at $0.75 \times 0.75 \times 3.3$ mm^3 with high T_2-weighting (sequence T_2 Blade), showing high contrast between fibrosis and tumor. In addition, a high resolution image with much less contrast is acquired (sequence 3D Space: $0.6 \times 0.6 \times 1$ mm^3), to accurately represent the anatomy of the region of interest. These images contain a high level of redundancy, which might clearly be exploited by the proposed SR approach to produce images with both high spatial resolution and clinically significant contrasts.

Profile of the candidate

The ideal candidate holds a Master/Engineer degree and has a strong background in image processing, applied mathematics and optimization. She/he has a very good level of English, both oral and written, and has good Python and C++ programming skills. Basic knowledge on MRI is a plus, although not compulsory.
She/he also has a deep interest in the field of medical imaging, and motivated to tackle both fundamental and applicative tasks. Very good communication skills are expected since the PhD. includes interactions with a large variety of domains including researchers, radiologists, and clinical staff.

Position details

The PhD. position is funded by Siemens Healthcare through a CIFRE (Conventions industrielles de formation par la recherche), a fixed-term 3 years contract (net salary around 2000 € net/month). The PhD. will mainly take place at CREATIS (Campus de la Doua, Villeurbanne), a biomedical and multidisciplinary research laboratory, including about 200 persons, which addresses both clinical and fundamental aspects of medical imaging. The candidate will be part of the team MAGICS, which research activities focus on the development of MRI and optics imaging modalities. The candidate is also expected to spend a significant amount of time at the CLB, to facilitate the transfer and perform the validation of his work.

Contacts

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References

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[3] Eric Van Reeth et al. "Super-resolution in magnetic resonance imaging: A review". In: *Concept in Magnetic Resonance - Part A* 40A.6 (2012), pp. 306–325. ISSN: 1552-5023.

[4] Jong Chul Ye. "Compressed sensing MRI: a review from signal processing perspective". In: *BMC Biomedical Engineering* 1.1 (2019), pp. 1–17.