Report on exchange visit to Medical Imaging Research Center, Katholieke Universiteit Leuven (KUL) at Leuven, Belgium

Spatially-variant Strength for Anatomical Priors in PET Reconstruction

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Summary

The main intention of the visit was to explore the use of a spatially variant penalty strength in penalized image reconstruction using anatomical information. As Parallel Level Sets (PLS) [1] has shown promising results in literature, it was chosen to be incorporated into the previously proposed preconditioned algorithm (L-BFGS-B-PC) [2, 3] for achieving both good image quality and fast convergence rate. Since the penalty function has been well-studied by the host group, the other purpose of this exchange was to learn from their knowledge and experience on parameter optimization for PLS. The software developed (on top of STIR) during the visit can be used as a starting-point for integration into the CCP PETMR software which would allow users to utilize PLS with anatomical information derived from MR images during PET reconstructions.

During this visit I interacted with several members of the group of Prof.

J. Nuyts, most intensively with Dr Anna Turco and Dr Georg Schramm. In addition to helping me build up essential knowledge for the proposed joint project, they also provided plenty information regarding live in the center and the city so that I could get used to the new environment quickly and have a productive visit.

Activities

Internal meeting

On the first day, I was asked to give a brief presentation regarding what I have done before and what I would like to achieve during the stay. We discussed the potential benefits and challenges of using a spatially variant penalty strength with the proposed algorithm (L-BFGS-B-PC) and the selected anatomical penalty function (PLS). We also arranged two joint SKYPE meetings between KUL and UCL in the following 2 weeks to discuss the simulation design for demonstrating the benefits.

Penalty function implementation

Since the performance of PLS was different between my implementation and theirs, we decided to try to synchronize the implementation first. We then realized that we were looking at different versions of PLS (related to smoothing terms, see [1], which KUL is not using). However, this comparison allowed me to debug my own original implementation with their help. We also spent some time on debugging a first implementation of the Bowsher prior in STIR, but this was left uncompleted due to time constraints.

Demonstration with digital phantoms

Initially, we used a 2-dimensional (2D) digital phantom to verify that the penalty function was able to work properly with L-BFGS-B-PC. We spent a full day on tuning parameters of the algorithm to have the desired edge preserving effect introduced by PLS. The performance of applying a spatially variant penalty strength with PLS was then evaluated by using a more realistic 3D XCAT phantom with several hot spots inserted at different locations.

One of the hot spots was absent in the anatomical image to be able to evaluate the influence from the anatomical penalty. The quantitative results on images reconstructed with and without the spatially variant penalty strength were compared for both PLS and the quadratic prior, as the later prior was widely used in practice.

Results

The outcome of this visit was primarily my increased understanding of anatomical priors and the corresponding parameter tuning. We have now implemented PLS for both 2D and 3D reconstructions in MATLAB to be used with STIR. The penalty function has been successfully incorporated into the proposed L-BFGS-B-PC and its performance with a spatially variant penalty strength was evaluated. The preliminary results were submitted to the 2017 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC). Future work will include evaluating the developed software with real PET/MR data shared by the host group.

References

[1] M. J. Ehrhardt, P. Markiewicz, M. Liljeroth, A. Barnes, V. Kolehmainen, J. S. Duncan, L. Pizarro, D. Atkinson, B. F. Hutton, S. Ourselin, K. Thielemans, and S. R. Arridge, "PET Reconstruction With an Anatomical MRI Prior Using Parallel Level Sets," *IEEE Trans. Medical Imaging*, vol. 35, no. 9, 2016.

[2] Y. J. Tsai, A. Bousse, M. J. Ehrhardt, B. F. Hutton, S. Arridge, and K. Thielemans, "Performance Evaluation of MAP Algorithms with Different Penalties, Object Geometries and Noise Levels," *IEEE MIC Conf. Proc.*, 2015.

[3] Y. J. Tsai, A. Bousse, C. W. Stearns, S. Ahn, B. F. Hutton, S. Arridge, and K. Thielemans, "Performance Improvement and Validation of a New MAP Reconstruction Algorithm," *IEEE MIC Conf. Proc.*, 2016.