PDD networks for medical image registration - Contributions to the Learn2Reg challenge

Lasse Hansen, Mattias P. Heinrich

Institut für Medizinische Informatik, Universität zu Lübeck
hansen@imi.uni-luebeck.de

Medical image registration plays a vital role in various clinical workflows, diagnosis, research studies and computer-assisted interventions. Currently, deep learning based registration methods are starting to show promising improvements that could advance the accuracy, robustness and computation speed of conventional algorithms. However, until recently there was no commonly used benchmark dataset available to compare learning approaches with each other and their conventional (not trained) counterparts. To overcome this shortcoming the 2020 MICCAI registration challenge, Learn2Reg (L2R), was initiated [1]. L2R comprises four complementary registration sub-tasks (brain MRI/US, inhale/exhale lung CT, abdominal CT, hippocampus MRI), that tackle the imminent challenges of medical image registration: learning from small datasets, estimating large deformations, dealing with multi-modal scans and learning from weak labels. At the same time L2R lowers the entry barrier for new groups in this emerging field with a simplified challenge design by providing pre-processed data (resampled, cropped, pre-aligned) and expects only voxel displacement fields.

Our methodical contribution to the L2R challenge is the adaptation of the probabilistic dense displacement (pdd) network to all tasks [2,3]. Features (handcrafted MIND-SSC or learned Obelisk) are extracted from the fixed and moving image. Next, a feature correlation layer evaluates a dense displacement space for each grid point. A final displacement field is obtained by encouraging smoothness with alternating filters that act on spatial (mean-field inference) and displacement dimensions (approx. min-convolutions) using unsupervised learning with a nonlocal metric loss. With our challenge entry we were able to rank first in two sub-tasks (brain MRI/US and respiratory lung CT), and second in the overall challenge and thus, could establish the PDD network as a fast and accurate general purpose registration framework for medical 3D scans.

References

1. Hansen L, Hering A, Heinrich M, et al.. Learn2Reg: 2020 MICCAI registration challenge; 2020. https://learn2reg.grand-challenge.org.
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3. Heinrich MP, Hansen L. Highly accurate and memory efficient unsupervised learning-based discrete CT registration using 2.5 D displacement search. In: MICCAI; 2020. p. 190–200. github.com/multimodallearning/pdd2.5.