TUTORIALS, Session 2: Medical Image Analysis

Part I: Thomas Fuchs, Memorial Sloan Kettering Cancer Center, New York: Computational Pathology in Practice: From Cluster to Clinic

Abstract: Pathology is in the midst of a revolution from a qualitative to a quantitative discipline. This transformation is fundamentally driven by machine learning in general and computer vision and deep learning in particular.
At Memorial Sloan Kettering we're building a computational pathology AI based on hundreds of GPUs and a petabyte of clinical data. The goal is not only to automated cumbersome and repetitive tasks, but to change the future of medical diagnosis and cancer research.

In the first part of the tutorial we will (i) give an introduction into and an overview of the field of computational pathology. We will discuss (ii) pivotal points at which machine learning can impact clinical work in pathology and cancer research and (iii) illustrate these with real-world projects.
The second part will be a deep dive into (iv) how large-scale machine learning systems are built in computational pathology, (v) how supervised and unsupervised deep learning is used for computer vision applications and (vi) how we bridge the gap to genomics and clinical outcomes.

Part II: Marcel Lüthi, University of Basel, Switzerland: Gaussian Processes for Surface and Image Registration

Abstract: Non-rigid registration is one of the central problems in computer vision and medical image analysis. Many different methods have been proposed during the last decades. A main differentiation factor between registration approaches is how they incorporate prior assumptions about possible deformations. In this tutorial we discuss how Gaussian processes can be used to interpret many of the classical registration approaches, such as spline-based methods, regularization methods based on differential operators, free-form deformations or non-rigid ICP approaches in a unified theoretical framework.

We will introduce a class of generative, parametric models, called Gaussian Process Morphable Models (GPMMs). GPMMs can be seen as a formal generalization of statistical shape models to the large class of models that can be defined using Gaussian processes. We show how GPMMs can be used to derive powerful registration schemes for surface and image registration. In particular, we will discuss how to build registration methods that work on multiple-scale levels, are spatially-varying, include deformations learned from data, or incorporate geometric constraints such as symmetries and matching landmarks.

The tutorial will be divided in three parts. In a first, theoretical part, we introduce the two core concepts: Gaussian processes to model deformation fields, and the Karhunen-Loeve expansion, which gives us a finite representation of the Gaussian process in terms of a linear combination of orthogonal functions. Using these two concepts, we then derive a simple registration algorithm based on Gaussian processes priors.

In the second part of the talk we discuss how we can derive complex prior models by combining kernels. In the last part, we show how these concepts can be used to solve practical surface and image registration problems using the open source software framework scalismo.