43075-01 Probabilistic Shape Modelling

Lecturers
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Introduction	22. March 2022
Discussion	29. March 2022

Before starting this exercise, you should have worked through Weeks 1 - 4 of the FutureLearn course. You should also have read the software tutorials corresponding to the material covered in these four weeks, on `https://scalismo.org/docs`.

Exercise 2 — Building a GP model

The goal of this exercise is to build a Gaussian process model for the femur. For this first model we only use one example femur. The shape variability is defined by defining a Gaussian process; I.e. by specifying a mean and covariance function. The derived model should be consistent with the prior information we have from exercise sheet 1 about the femur length and width. The model will later in the project be used to establish correspondence to the other training examples.

2.1. Building the GP Model

Write Scalismo code to build a Gaussian process model of the femur. As a reference, use the reference femur from the previous exercise. Use the code in tutorial 7 as a basis for your developments:
`https://scalismo.org/docs/Tutorials/tutorial07`.
Think about the following points and substantiate your answers with suitable experiments.

- What is the influence of the scale and smoothness parameters?
- What are reasonable parameters for the scale parameter s and the smoothness σ?
- How does the smoothness of a kernel (i.e. the parameter σ of the Gaussian kernel) influence the number of basis functions that are needed to approximate a given Gaussian process? Can you explain this?
- What are the units of these parameters (mm, mm^2, ...)?
- Would it make sense to combine kernels with different scale and smoothness? What would this achieve?
- If you answered yes to the previous question: Should the scale be large for the smooth kernels and small for the less smooth ones, or is it vice versa? Why?
- Think about other combination of kernels that could make sense for modelling femur shapes?
- How would you define a kernel that has more variance in the direction, which corresponds to the length of the femur?

The easiest way to quickly get an impression of the suitability of the model is to draw and visualize a few samples. Note that at this stage it is normal that the samples show deformations that are anatomically implausible. The reason is that we have only incorporated smoothness assumptions in our model, and not used acual example data to learn the covariance function. It is, important, however, that the modelled shape variation should be able to represent all anatomically correct femur shapes.

2.2. Analysing the model

In order to understand if our model is useful for explaining femur shapes, we should also take our prior information into account. In last week's exercise, we have measured the length and width of the femur. Repeat this experiment, but for samples from the model that you built. Compare them with the measurements from last week's exercise.