43075 Probabilistic Shape Modelling

Lecturers
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Exercise 2 — Gaussian process models

Introduction	17. March 2020
Deadline	**31. March 2020** (Discussion / presentation during exercise session)

1. Femur project: Building a PCA model

The goal of this exercise is to perform the next step of the femur project. This time you will first choose a reference shape and build a Gaussian Process model. You will then use this GP model to establish correspondence to all the other training examples. Once you have correspondence, you can use it to build a PCA model.

As a preparation, work through weeks 1 - 6 of the FutureLearn course.

1a. Building the GP model

In the last exercise you have already downloaded the data you need. Select one of the datasets as a reference shape and use it to build a Gaussian process model, which models smooth shape deformations (2nd part of Step 4.11 on FutureLearn.)

Think about the following points and perform experiments to find good kernels and parameters for your model.

- Does it matter which bone you choose as a reference shape? If it does, what would constitute a good reference?
- What are reasonable parameters for the scale parameter s and the smoothness σ?
  - What is the unit of these parameters (mm, mm^2, ...)?
  - How does drawing random samples from the model help you to decide if your model is appropriate
  - What is the influence of the scale and smoothness parameters (Experiment with them).
- Think about possibilities to combine kernels.
  - Does it make sense to combine kernels with different scale and smoothness?
  - 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?
- Think about other combination of kernels that could make sense for modelling femur shapes.

1b. Establish correspondence

Use the model that you build in the previous step to establish correspondence among all the data sets, using the methods explained in week 6 in the FutureLearn course.

Think about the following question:

- Should the surfaces be rigidly aligned before you establish correspondence? Why or why not?
- The ICP algorithm consists of two steps: Fitting the model and finding the closest point on the target. Do you take the closest points on the target shape as corresponding points or the points of the model after the fitting step? What would be the advantages/disadvantages of each possibility?
- How do you know that you have found good correspondence?
- What would be the consequences of having bad correspondences when building the model?

1c. Build a PCA model

From the previous step you should now have a set of femur surfaces which are in correspondence. Use them to build a PCA model of the femur.

- Make sure that you visualize the resulting model. Do all the instance look like valid femur shapes?

2. Theory questions

Think about the following questions:

- We can build a Gaussian process by specifying a Gaussian kernel as a covariance function. Why would we still use example data to build our shape models?
- How does the smoothness of a kernel (i.e. the parameter σ of the Gaussian kernel) influence the number of basis functions, which are needed to approximate a given Gaussian process? Can you explain this?
- What are the advantages and disadvantages of the parametric (low-rank) representations of a Gaussian process.
- What problems can occur when a Statistical Shape Model is built from too few example datasets? Give three different possibilities how this problem can be alleviated.