Exercise 08 for MA-INF 2201/MA-MOROB-M04 Computer Vision WS25/26
12.01.2026
Submission on 25.01.2026

Shapes

Task 1: Shape Template Models

The goal of this exercise is to match the landmarks outlining the shape of Remy to their corresponding locations in the image (Fig. 1).

1.1: Implementation

Use the landmarks in *rat.txt* to locate Remy (the grey/blue) rat in *rat.webp* through matching the shape template. You are free to use any of the methods discussed for inference (maximum likelihood, iterative closest points with line search, ...).

Figure 1: Image with the warped shape template.

(10 points)

1.2: Report

Write a concise report justifying the design choices made (edge detector, inference method, etc.) and their effect on the qualitative and quantitative performance, alongside appropriate visualizations. Additionally, discuss the following point:

- What would be the expected outcome when applying snakes instead of shape template models to segment Remy?

(5 points)

Task 2: Statistical Shape Models

Between the extremes of snakes and template models is the more flexible family of Statistical Shape Models. In this exercise, you are tasked to implement such a model from scratch.

2.1: Generalized Procrustes Analysis

The *hands_train.npy* file contains 56 landmark points (x and y coordinates) from the hand contours of 38 different subjects. The goal of this task is to align the data with affine transformations via generalized Procrustes analysis. Include a plot of the shapes before and after the alignment in the report.

(7 points)

2.2: Statistical Shape Model

2.2.1: Subspace model

Build a PCA-based statistical shape model M using the aligned data obtained in the previous step. Choose the number of basis functions N to be the minimum number of principal components preserving 90% of the energy. Visualize the effect of varying the ϕ_ks.

Important: implement PCA by yourself, do not directly use a pre-existing library function. You are allowed to use np.linalg.eig or np.lingalg.svd for this task.

2.2.2: Probabilistic subspace model

Extend the subspace model to a Probabilistic PCA-based statistical shape model. Visualize the effect of varying the ϕ_ks.

Important: implement PPCA by yourself, do not directly use a pre-existing library function. You are allowed to use np.linalg.eig or np.lingalg.svd for this task.

(8 points)

2.3: Inference

Express the test shape in *hands_test.npy* in terms of basis functions of the two PCA models from section *2.2*. Reconstruct the test shape and visualize the original and the reconstructed shapes, and calculate the MSE between them.

(5 points)

2.4: Report

Write a concise report justifying the design choices made and their effect on the qualitative and quantitative performance, alongside appropriate visualizations. Include an image with the shape template overlaid on the image. Additionally, discuss the following points:

- How sensitive is the Procrustes analysis to the initialization?
- How much do the standard and probabilistic results differ? Why?

(5 points)

Questions If you have questions or find any ambiguities/mistakes, please contact Lars Doorenbos (doorenbos@iai.uni-bonn.de).

Grading: Submissions that generate runtime errors or produce obviously useless results (e.g. nans, inf or meaningless visual outputs) will receive at most 50% of the points.

Plagiarism: Plagiarism is prohibited. If your solution contains copied codes (i.e., from other students), you will receive **0 points** for the entire exercise sheet.

Submission: You can complete the exercise in a group of two, but only one submission per group is allowed. Include a *README.txt* file with your group members into each solution. Points for solutions without a README file will only be given to the uploader.