Medical Image Processing for Interventional Applications

Statistical Shape Models – Part 1

Online Course – Unit 44

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Topics

Introduction

Segmentation is difficult in presence of noise and artifacts (e.g. streaks).

$\rightarrow$ Prior knowledge about the general shape of the organ is helpful.

Problem: Human anatomy is very different between different subjects.

$\rightarrow$ Description needs to be able to describe these variations.

Model-based methods

- Applied since 1990s successfully in 2-D
- Expansion to 3-D available and applied successfully

- Model describes expected shape and appearance
- Applied in a top-down approach in contrast to low-level methods
- Increased stability compared to low-level methods

- Single template models only useful in industrial applications (e. g., no variations expected)
- In medical applications $\rightarrow$ Variation needs to be modeled!

Other Approaches

Freely deformable models:

- Seminal snakes (smoothness + image fit)
- Deformable simplex mesh (template shape + image fit)

$\rightarrow$ Models can be adopted to specific shapes but do not allow to model variations.

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Level-sets (see also Cremers, Rousson, Deriche, 2007):

- Implicit shape representation with regional or edge-based features
- Learning-based methods can be integrated in the energy function.
- Distance maps do not form a linear space:
  - $\rightarrow$ They can lead to invalid shapes (in cases with too much variations in the training data).
  - $\rightarrow$ Transformation into a different space is beneficial.

General Structure

1. Shape representation
2. Extraction of principal modes
3. Finding correspondences between shapes

Shape Representation

Input:

- Segmented volumetric images
- Surface meshes
- Any other shape representation that can be converted into one of the above (B-Spline, NURBS)

$\rightarrow$ Representation is crucial for the resulting **statistical shape model**.

Landmarks and Meshes

- Simple, but very generic
- Fixed number K of points as a long vector:

$$\boldsymbol{x} = \begin{pmatrix} x_1 \\ y_1 \\ z_1 \\ \vdots \\ x_K \\ y_K \\ z_K \end{pmatrix}$$

- Points are referred to as ***landmarks***.
  (They do not need to be actual anatomical landmarks $\rightarrow$ ***semi-landmarks***.)
- If connectivity information available $\rightarrow$ mesh
- Landmarks only as a basis for a statistical shape model yield a **point distribution model** (PDM).

Other Models

- Medial models:
  - Use center lines and radii $\rightarrow$ centerline points and vectors pointing to boundary
  - Called ***m-rep*** in 3-D
- Fourier surfaces: Composition of a certain topology from base shapes
- Spherical Harmonics: Composition of spheres to describe a closed surface
- NURBS: **N**on-**u**niform **r**ational **B-s**plines
- Wavelets, etc. ...

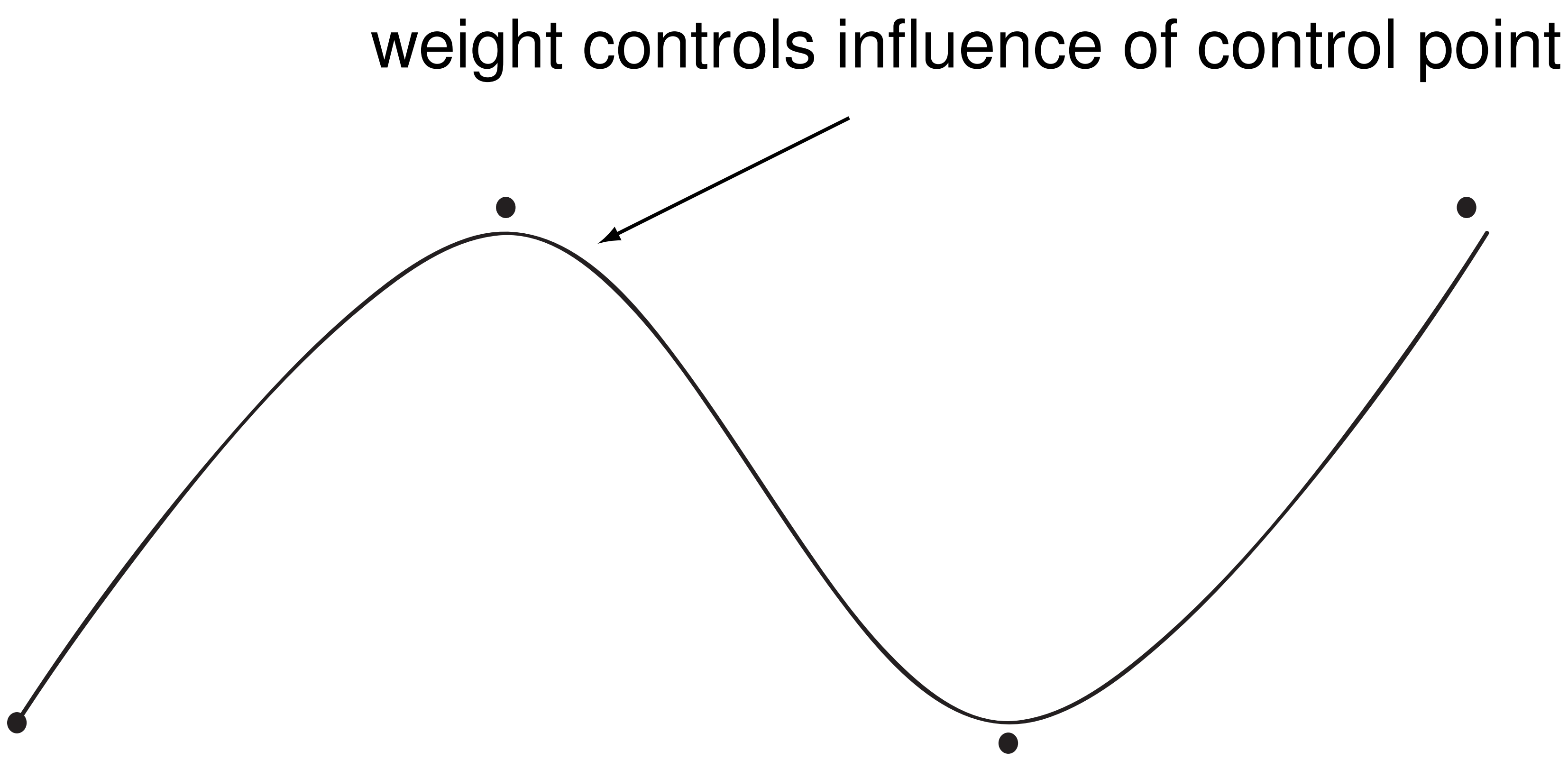

Figure 1: NURBS example

Topics

Statistical Shape Models

- Introduction
- Overview of Methods
- Shape Representation

Summary

- Take Home Messages
- Further Readings

Take Home Messages

- Statistical shape models are used in a series of approaches to incorporate prior data into a segmentation algorithm.
- A large variety of methods has been researched which can be studied starting with the review of Heimann and Meinzer, 2009.
- Shape can be represented simply by so-called landmarks, for example, but there exist other elaborate models as well.

Further Readings

These review papers are a good start for learning more about the methods described in this unit:

- Tobias Heimann and Hans-Peter Meinzer. "Statistical Shape Models for 3D Medical Image Segmentation: A Review". In: *Medical Image Analysis* 13.4 (Aug. 2009), pp. 543–563. DOI: 10.1016/j.media.2009.05.004
- Daniel Cremers, Mikael Rousson, and Rachid Deriche. "A Review of Statistical Approaches to Level Set Segmentation: Integrating Color, Texture, Motion and Shape". In: *International Journal of Computer Vision* 72.2 (Apr. 2007), pp. 195–215. DOI: 10.1007/s11263-006-8711-1

They also contain lots of references for further reading.