Image Analysis

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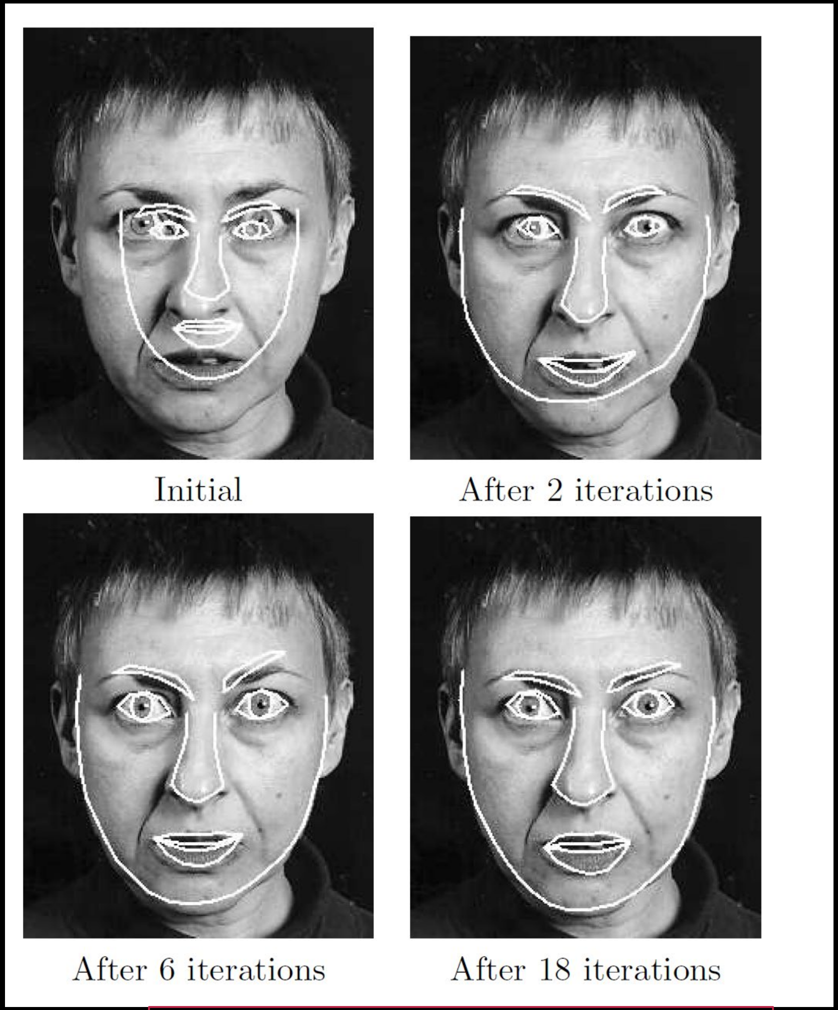
Lecture 12 – Active shape models

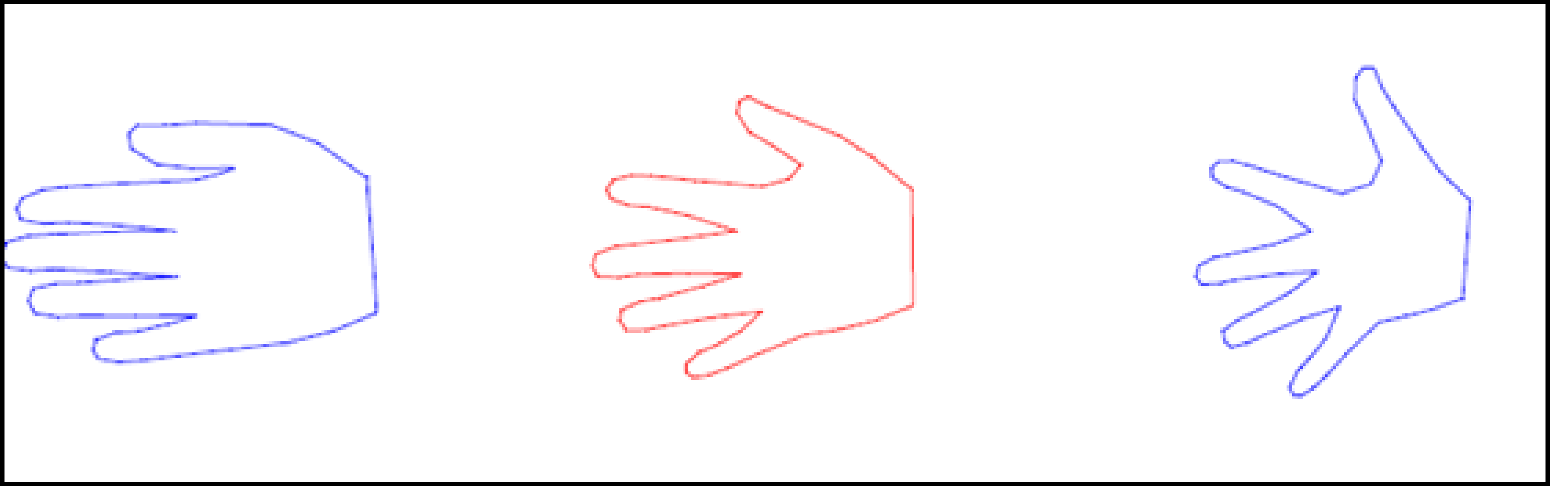


Tim Cootes: Active shape models

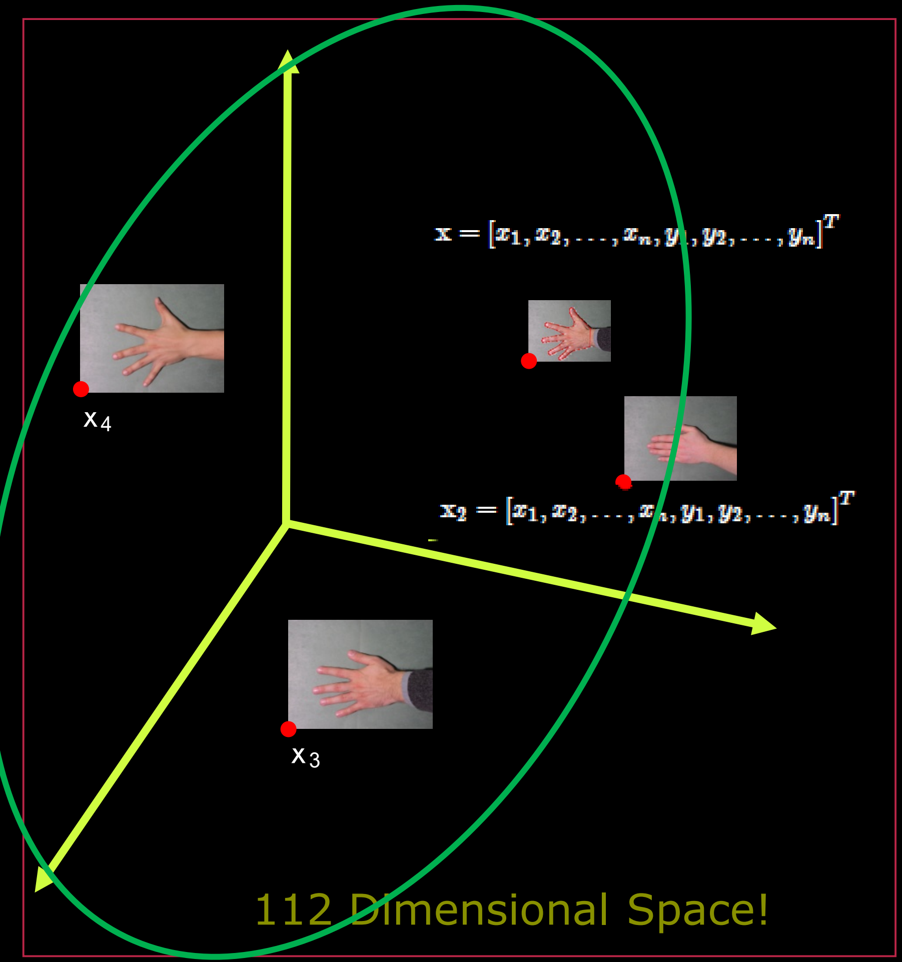
Today's Learning Objectives

- Describe how shapes can be synthesized using the shape space
- Describe the generative model based on a statistical shape model
- Describe the concept of analysis by synthesis
- Describe how the Eigenvectors and Eigenvalues can be used to constrain a shape model
- Describe how a statistical shape model can be fitted using the gradients in an image
- Describe how a statistical shape model can be fitted by modelling local variation
- Explain the problem of strong priors in statistical models

We have a statistical model of shape

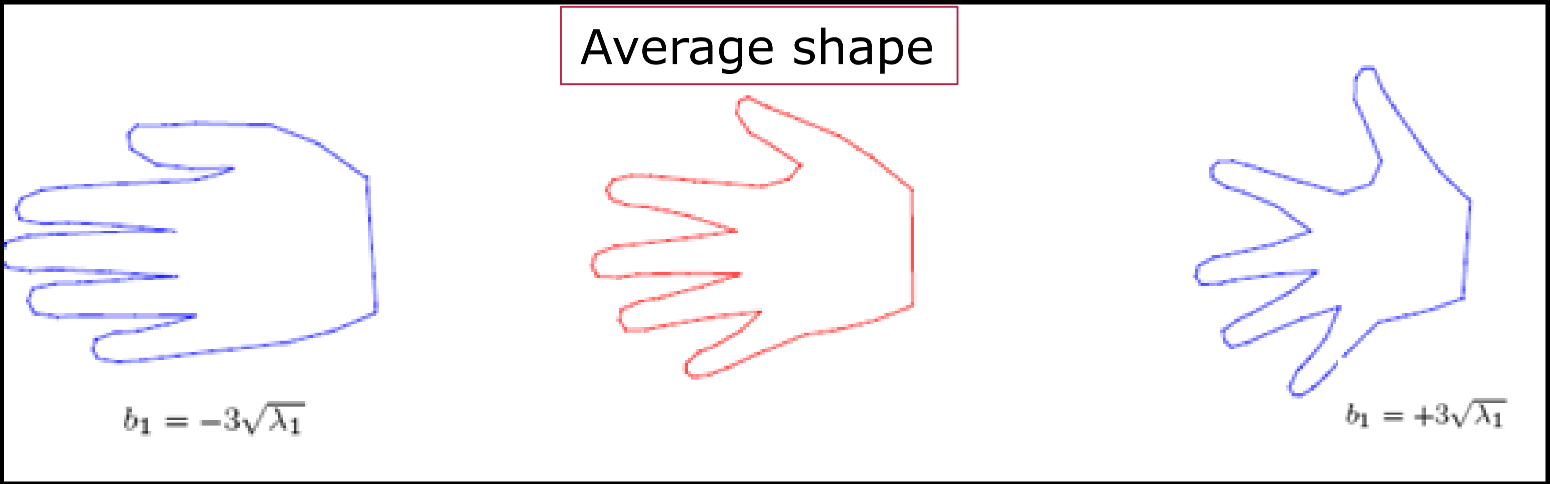


Shape space



- A mapping of the shape space
- PCA based description of the "hand space"

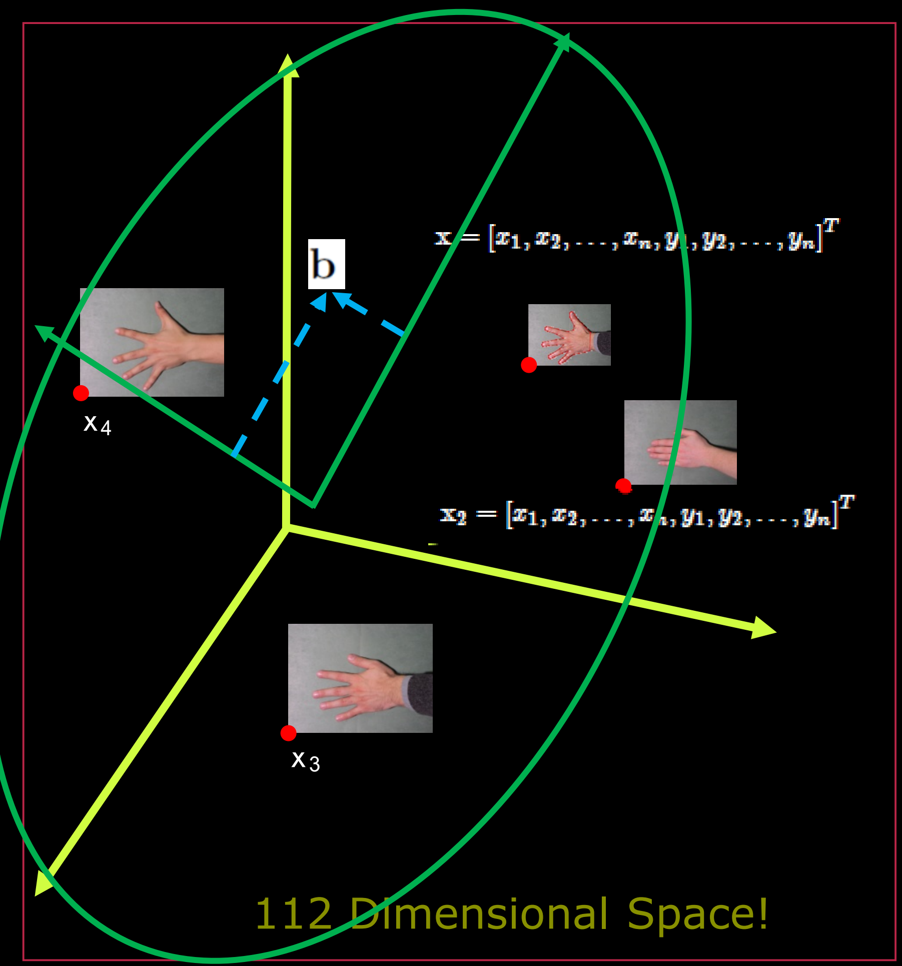
Synthezising new shapes



$$\mathbf{x} \approx \bar{\mathbf{x}} + \mathbf{\Phi b}$$

Φ contains the t eigenvectors

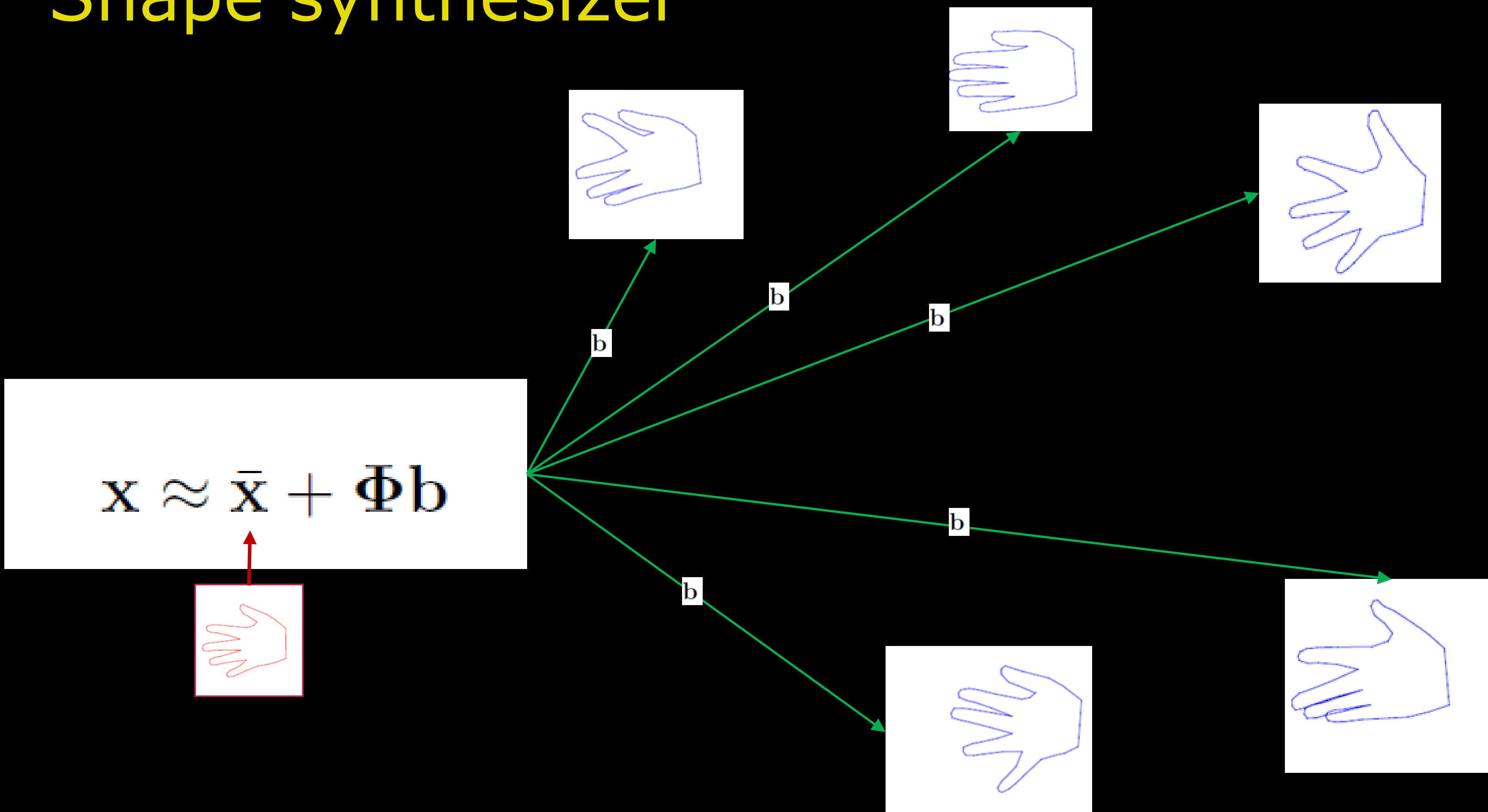
Shape space



- We can *sample* new shapes by moving around in shape space
- b are the *coordinates* in shape space
- The shape space is defined by the Eigenvectors
- b are the coordinates on the Eigenvectors

$$\mathbf{x} \approx \bar{\mathbf{x}} + \Phi \mathbf{b}$$

Shape synthesizer

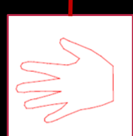


A *generative* model

Shape synthesizer

b

$$\mathrm{x} \approx \bar{\mathrm{x}} + \Phi \mathrm{b}$$



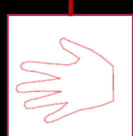
A *generative* model

- b needs to be *constrained*
- Should be bounded by the learned shape space
- Using the size of the Eigenvalues

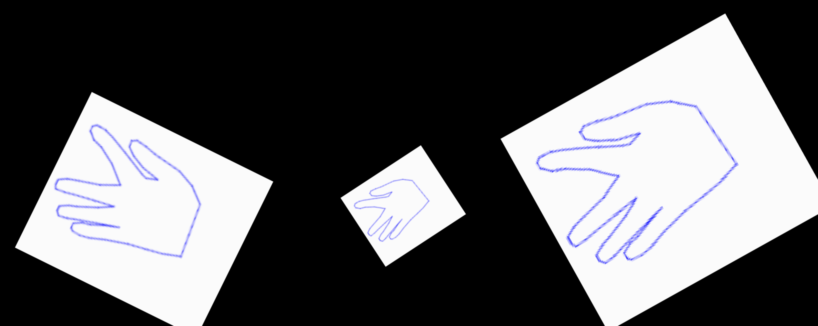
$$-3\sqrt{\lambda_1} < b_1 < 3\sqrt{\lambda_1}$$

Shape synthesizer + geometrical transformation

$$\mathrm{x} \approx \bar{\mathrm{x}} + \Phi \mathrm{b}$$



- Adding a geometrical transformation
  - Translation X_t, Y_t
  - Scale s
  - Rotation θ

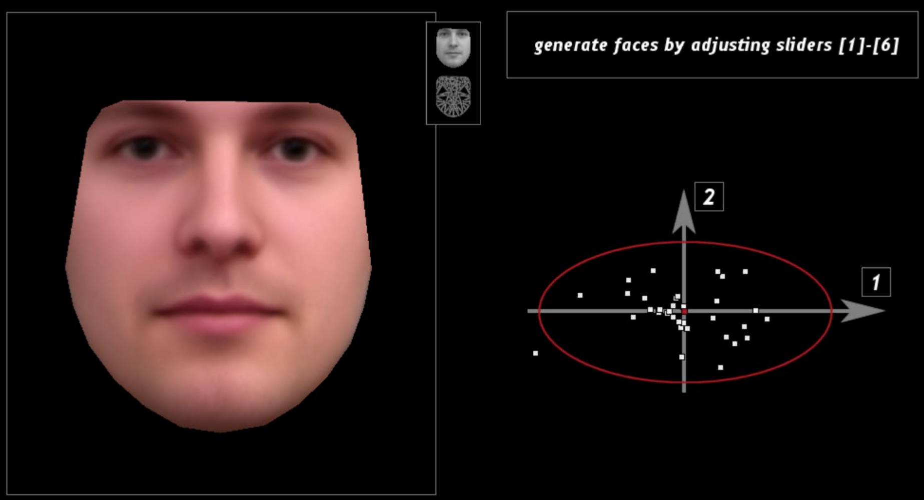


A *generative* model

Pattern recognition

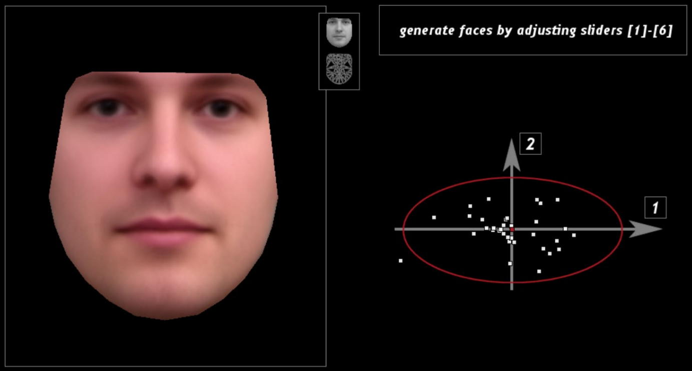
- Classical image analysis
- Hand crafting features
  - Eye detector
  - Nose detector
  - Mouth detector

Analysis by synthesis



- We have a generative model
  - A face synthesizer
  - A face is represented by a *few* parameters: *b*

Analysis by synthesis



Generative model

Target

- Compare synthetic face with target face
  - Sum of squared differences
- Change parameters of model until difference is minimal
  - Position, rotation, scaling
  - b vector

Similar to image registration with a deformable *moving image*

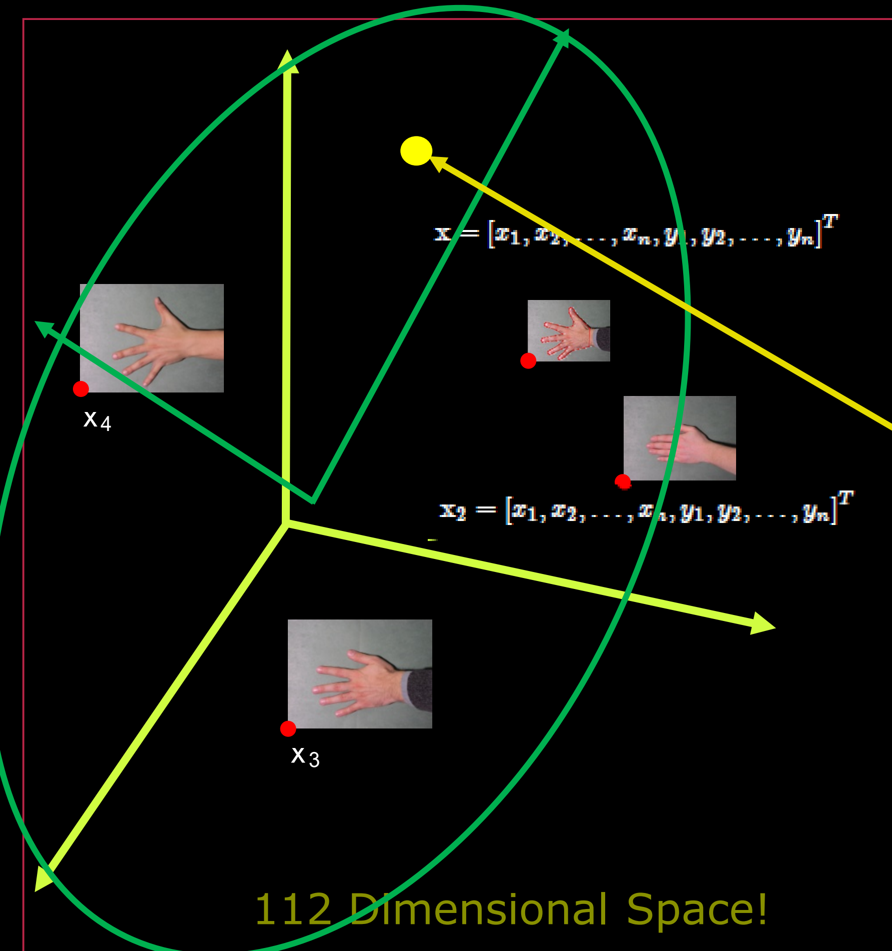
Fitting a shape and appearance model

- Finding the optimal set of parameters: position, rotation, size and b vector of model
- An *optimization* problem
- In general very hard
- Custom solutions exist

Left: Fitted model
Right: Real photo

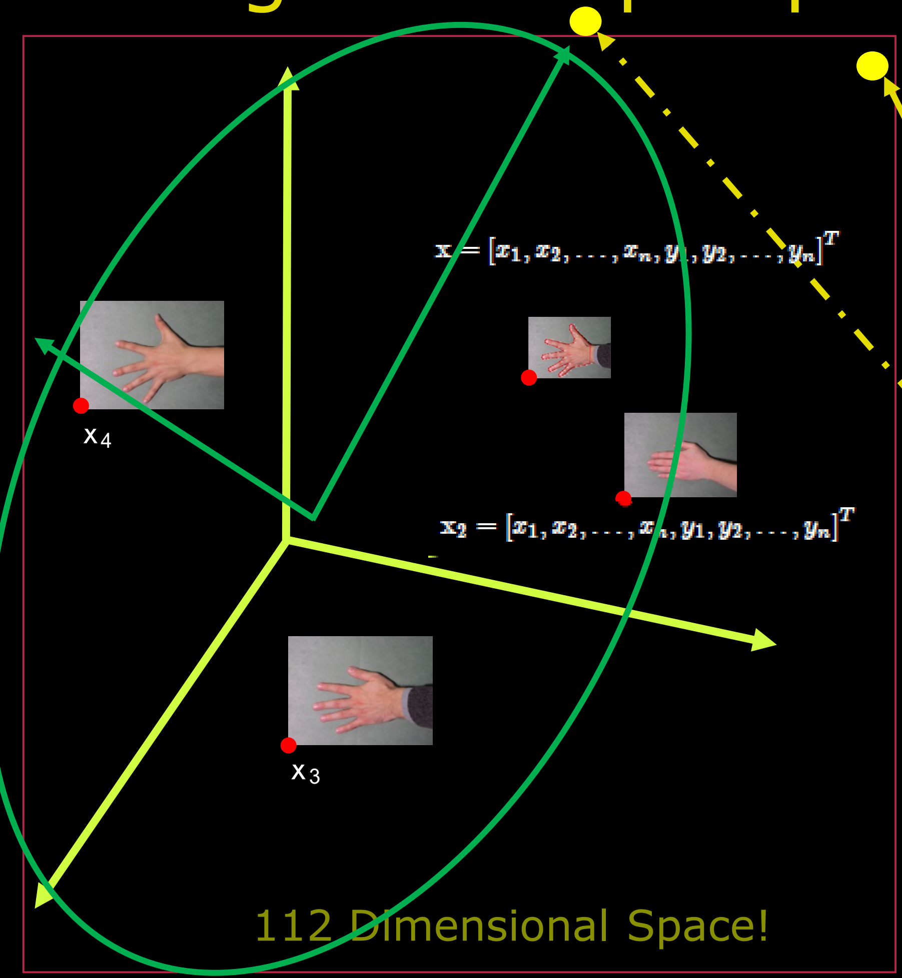
Tim Cootes: Active Appearance models

Using the shape space



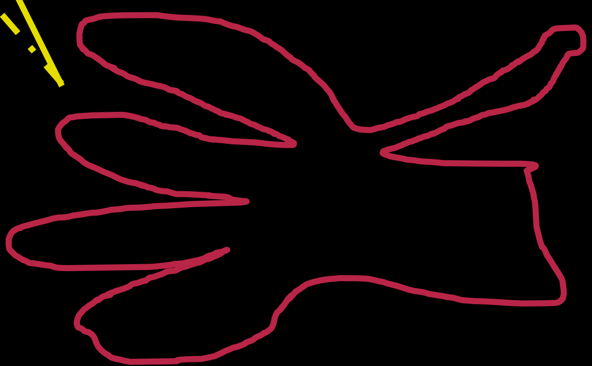
- Given a shape
  - It can be placed in shape space

Using the shape space

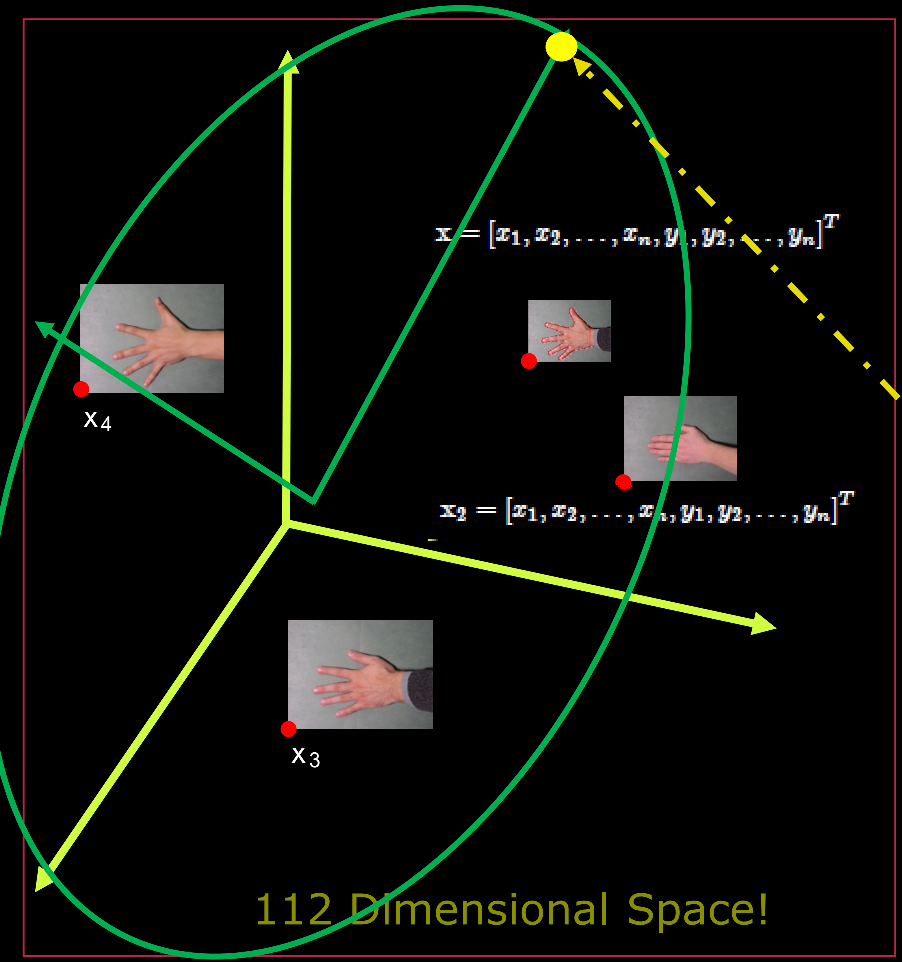


- Given a shape
  - It can be placed in shape space
- It can be projected to the Eigenvectors

Not anatomically plausible



Using the shape space



- Given a shape
  - It can be placed in shape space
- It can be projected to the Eigenvector
- And bounded by the Eigenvalues

$$\boxed{-3\sqrt{\lambda_1} < b_1 < 3\sqrt{\lambda_1}}$$

Closest anatomically plausible shape

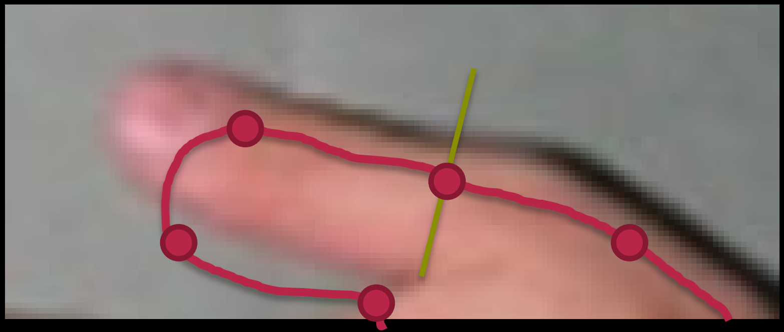
Course evaluation

- Please all use DTU Inside to evaluate the course!
- What did you like and what worked well?
- What do you think can be improved?
  - Perhaps how?

Fitting the active shape model to a new image

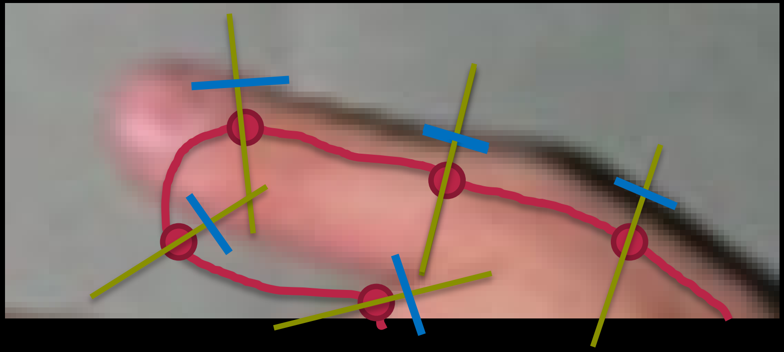
- Place the average shape on top
- Fit model points to actual image

Fitting the active shape model to a new image



- Fit model points to actual image
- For each point:
  - Search along normal direction
  - Find highest grey level gradient

Fitting the active shape model to a new image



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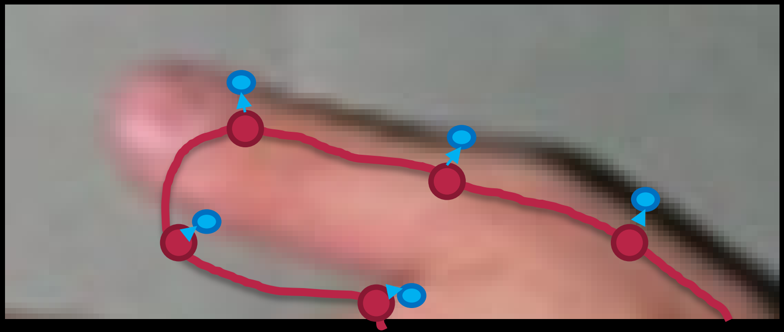
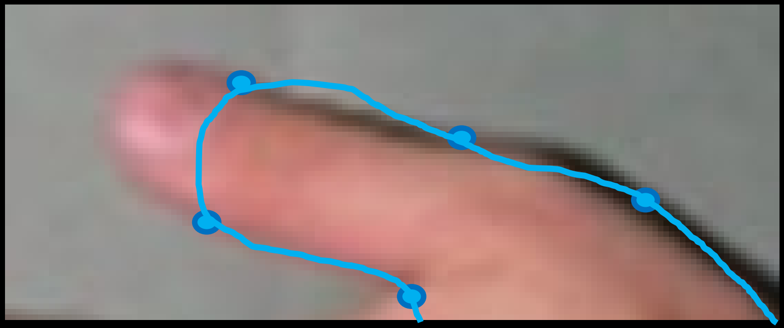


- Compute translation, rotation and scaling
  - Landmark based registration
- Move points to create new shape

Fitting the active shape model to a new image



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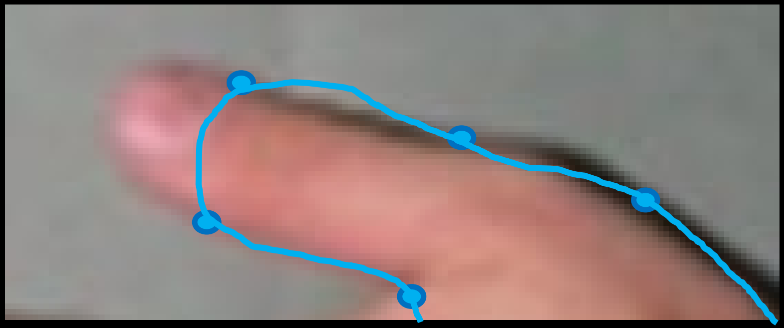


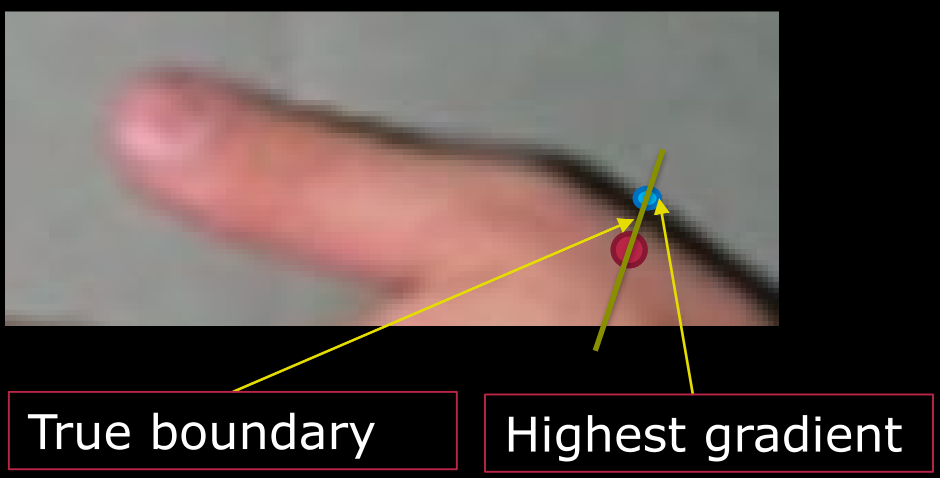
- Put new shape in shape space
- Project on Eigenvectors
- Constrain using Eigenvalues
  - Also called *regularization*

Result: Shape that matches image and that is anatomically plausible

$$-3\sqrt{\lambda_1} < b_1 < 3\sqrt{\lambda_1}$$

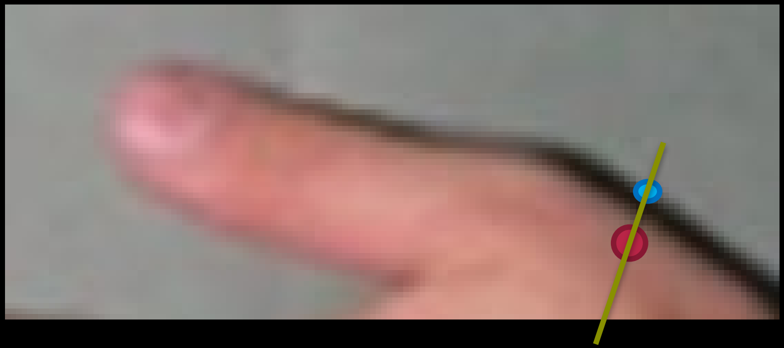
Modelling local structure

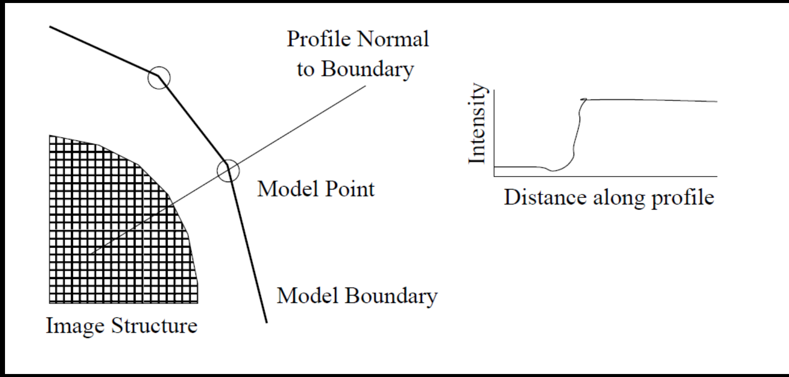
- The boundary is not always where there is highest gradient



Modelling local structure

- Sample along profile
- Normalise using sum of values



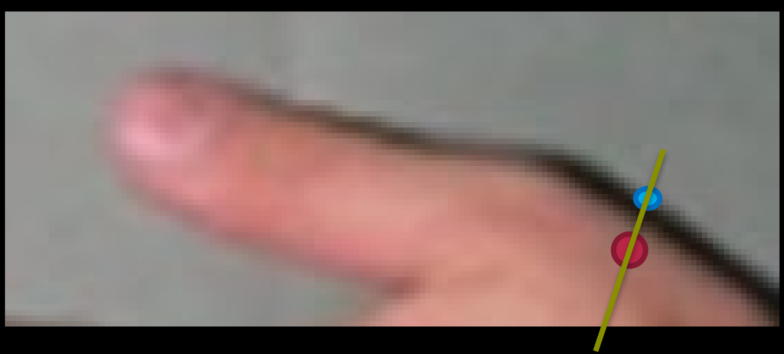


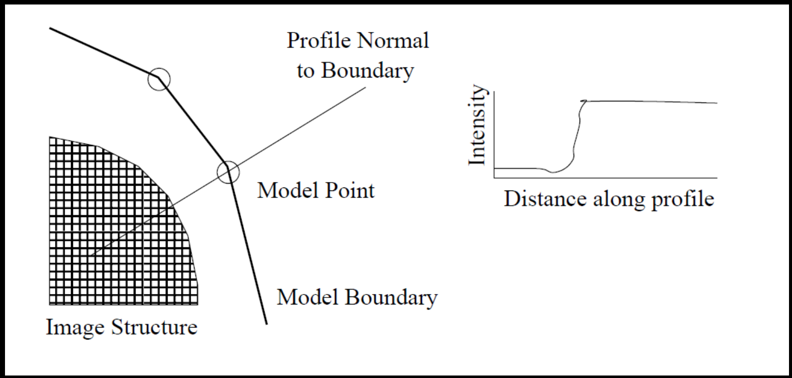
$$\mathbf{g}_i \rightarrow \frac{1}{\sum_j |g_{ij}|}\mathbf{g}_i$$

Modelling local structure

- Approximate distribution of samples
  - Multivariate Gaussian

mean $\bar{\mathbf{g}}$ and covariance $\mathbf{S}_g$

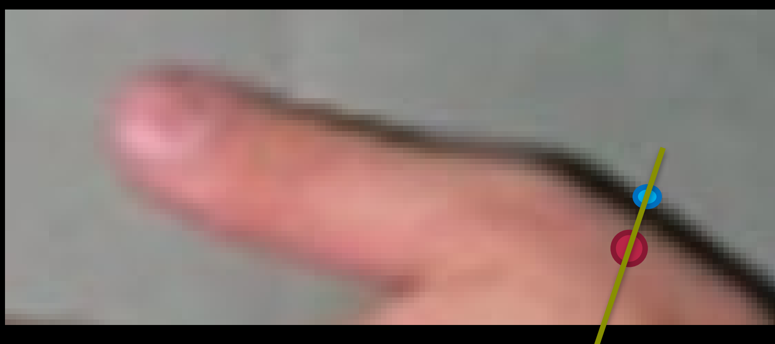




$$\mathbf{g}_i \rightarrow \frac{1}{\sum_j |g_{ij}|}\mathbf{g}_i$$

Modelling local structure

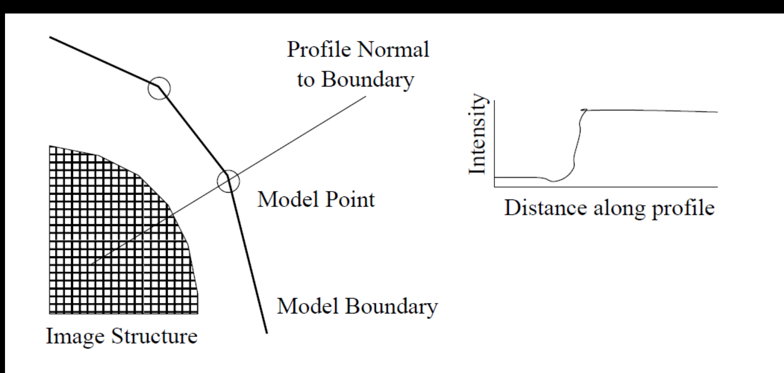
- Instead of using the gradient to search, a quality of fit is used:



The quality of fit of a new sample, $\mathbf{g}_s$, to the model is given by

$$f(\mathbf{g}_s) = (\mathbf{g}_s - \bar{\mathbf{g}})^T \mathbf{S}_g^{-1} (\mathbf{g}_s - \bar{\mathbf{g}})$$

This is the Mahalanobis distance of the sample from the model mean.



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Modelling local structure

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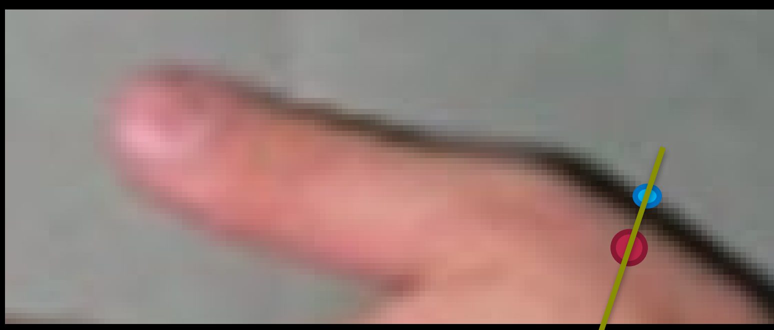

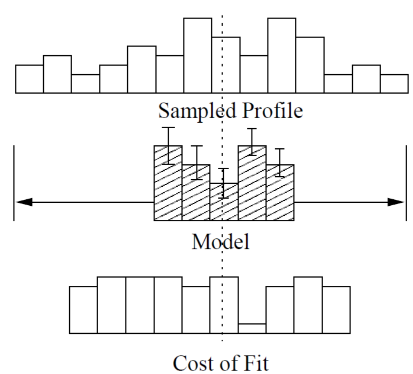

Search along sampled profile to find best fit of grey-level model

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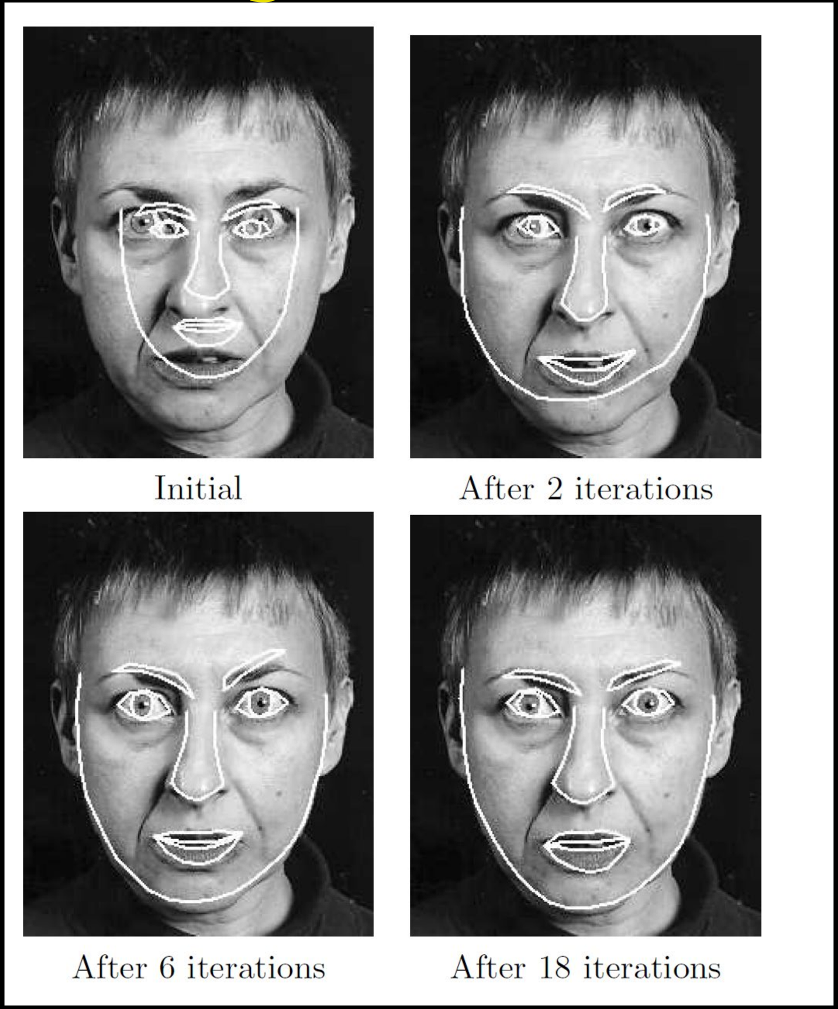
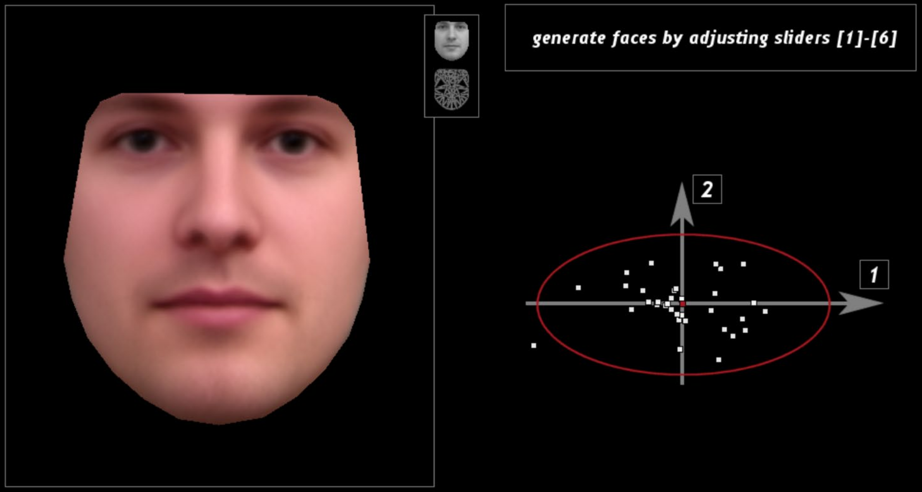
Fitting to a new shape



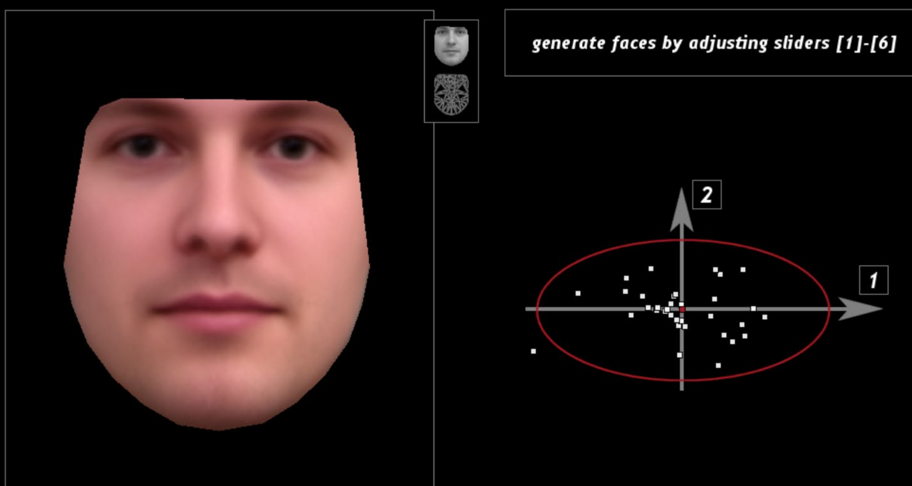
Tim Cootes: Active Appearance models

The problem with strong priors



- A *prior*
  - What was known before
  - A statistical shape model

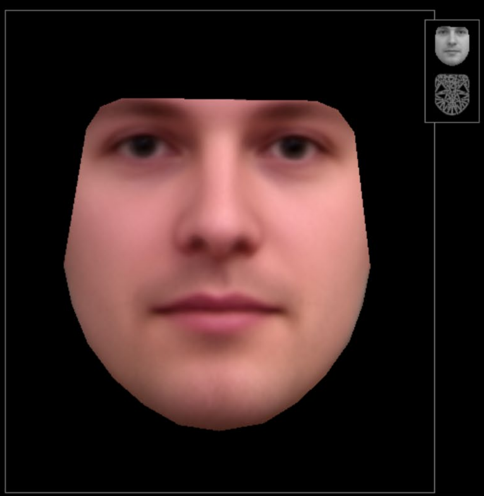
The problem with strong priors

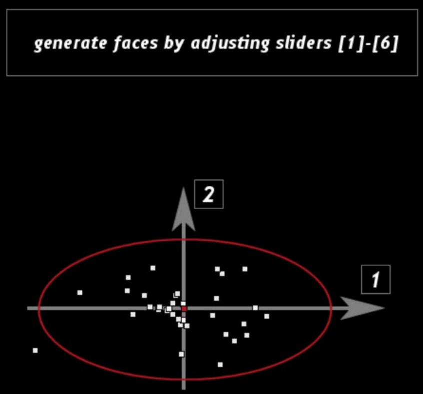


- Model is trained on images of adults
- Will try to force all fits to *look like adults*
- Will not work well with images outside the *prior*

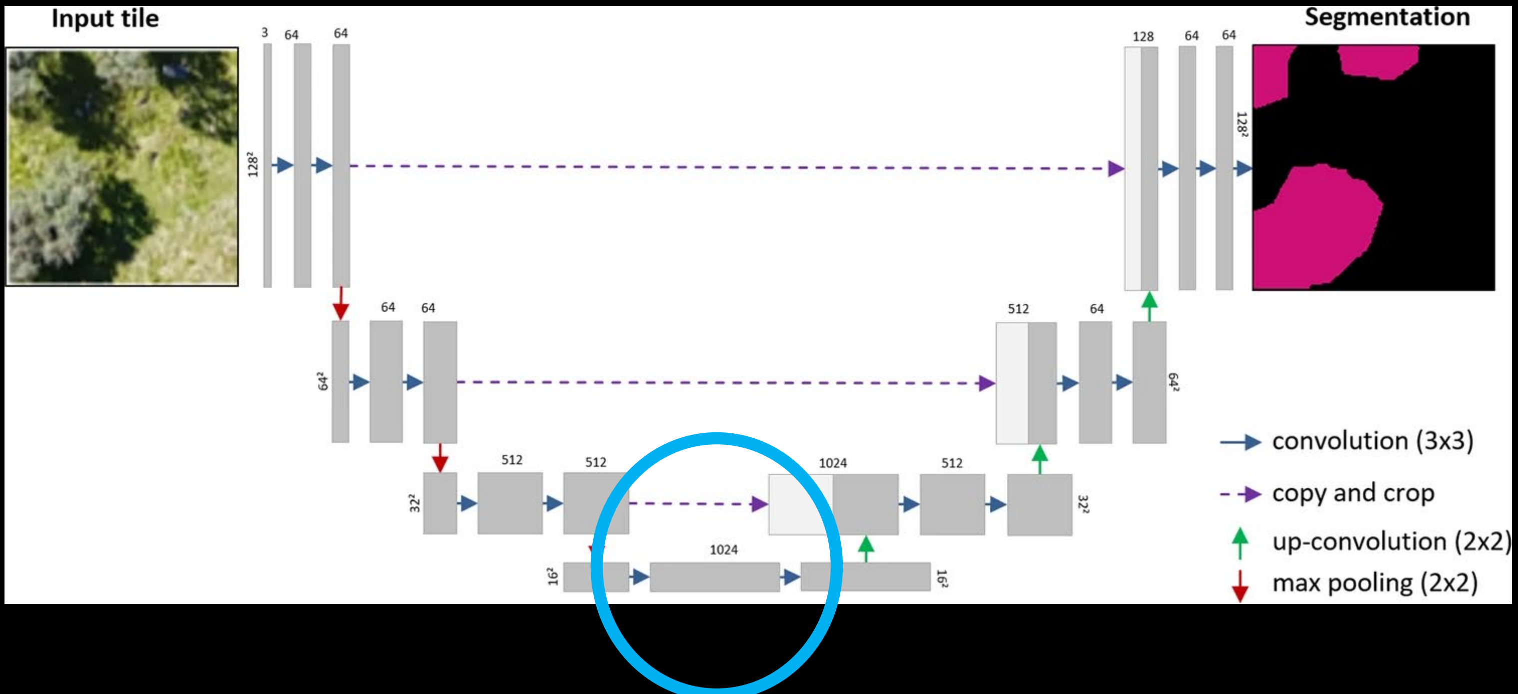
Testing the model

- Important to the model on independent data
- How it *generalizes*
- Is the prior too strong?





PCA space vs. Latent space



Latent space

Kattenborn, T., Eichel, J. & Fassnacht, F.E. Convolutional Neural Networks enable efficient, accurate and fine-grained segmentation of plant species and communities from high-resolution UAV imagery. *Sci Rep* **9,** 17656 (2019).

Next week

- Digital test exam
- Examples of advanced topics in image analysis