Probabilistic shape modelling

Marcel Lüthi

Graphics and Vision Research Group
Department of Mathematics and Computer Science
University of Basel

People involved in this course

Marcel Lüthi
- Lecturer
- Main responsible for the course

Ghazi Bouabene
- Tutor
- Main responsible for Tutorials / Exercises and Project

Thomas Vetter
- Guest lecturer: Computer Graphics, Face Image Analysis

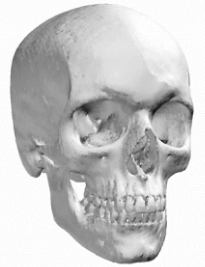
Graphics and Vision Research Group

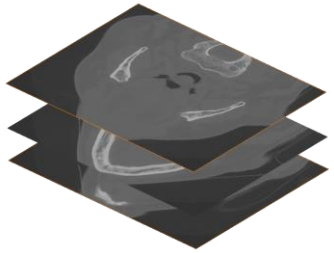
Anaysis of 2D Face photographs

Model-based image analysis

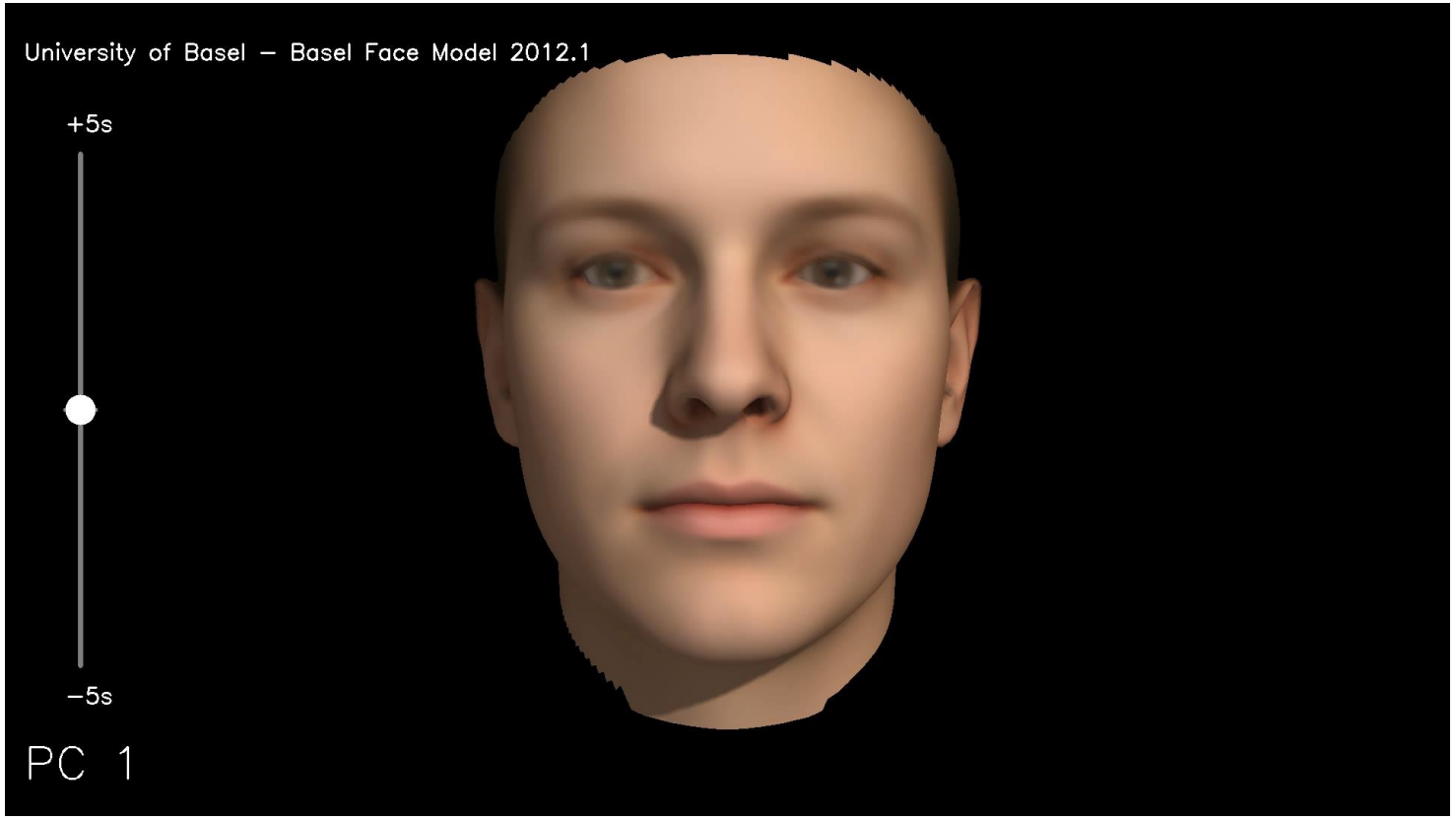
Other i… analysis projects

Medical image Analysis

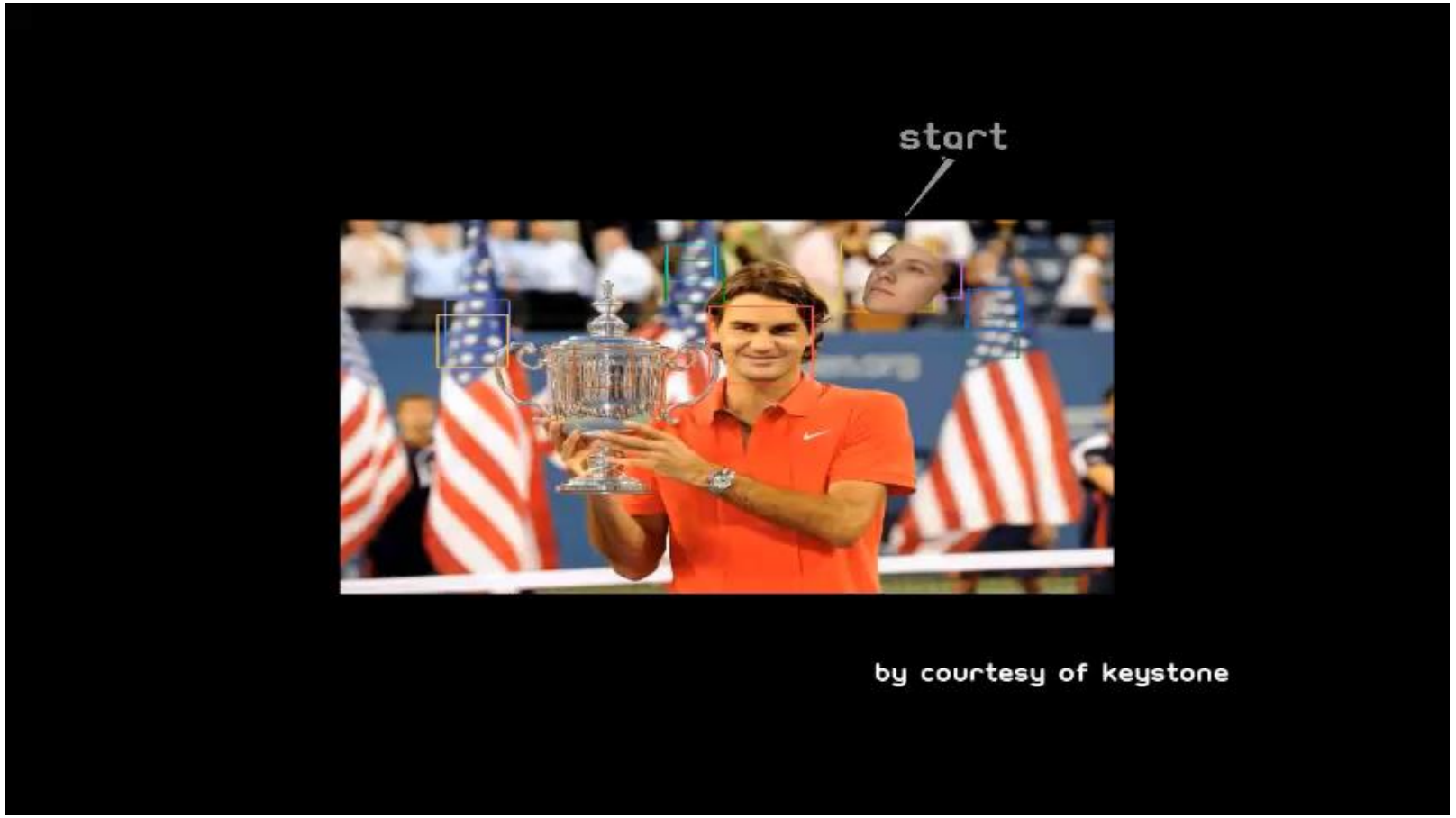




Model of a face



Analysis of an image using the model



What we are discussing today

- Probabilistic shape modelling
  - The course in a nutshell
  - Demo
  - Connections to other courses

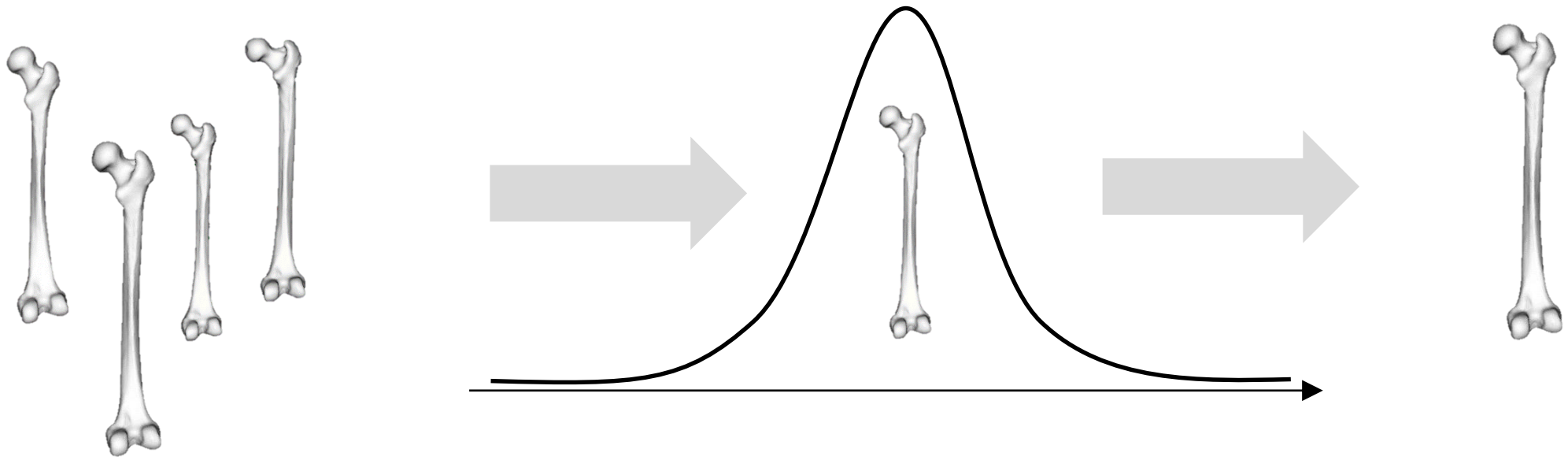
- Course organization
  - What exactly is this online course?
  - How do I get the credit points?

Main goal: Get everybody motivated for the topic!

Statistical shape models

Statistical Shape model: A probability distribution of shapes, learned from example data.

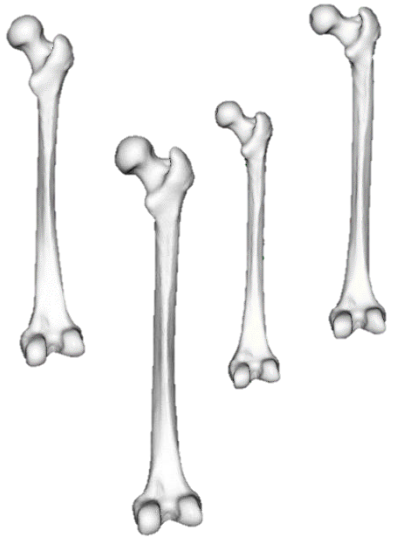
Example shapes

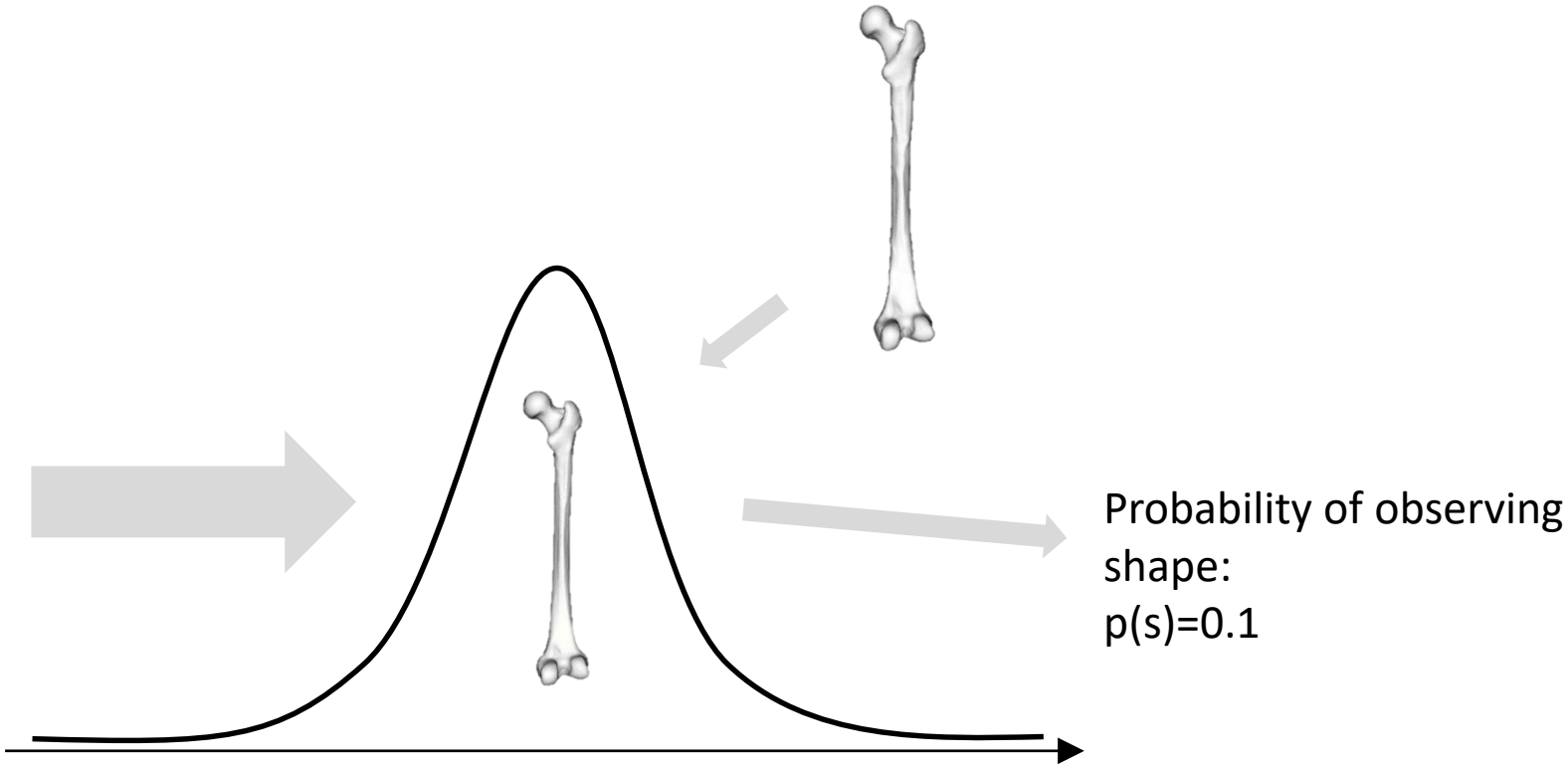


Statistical shape models

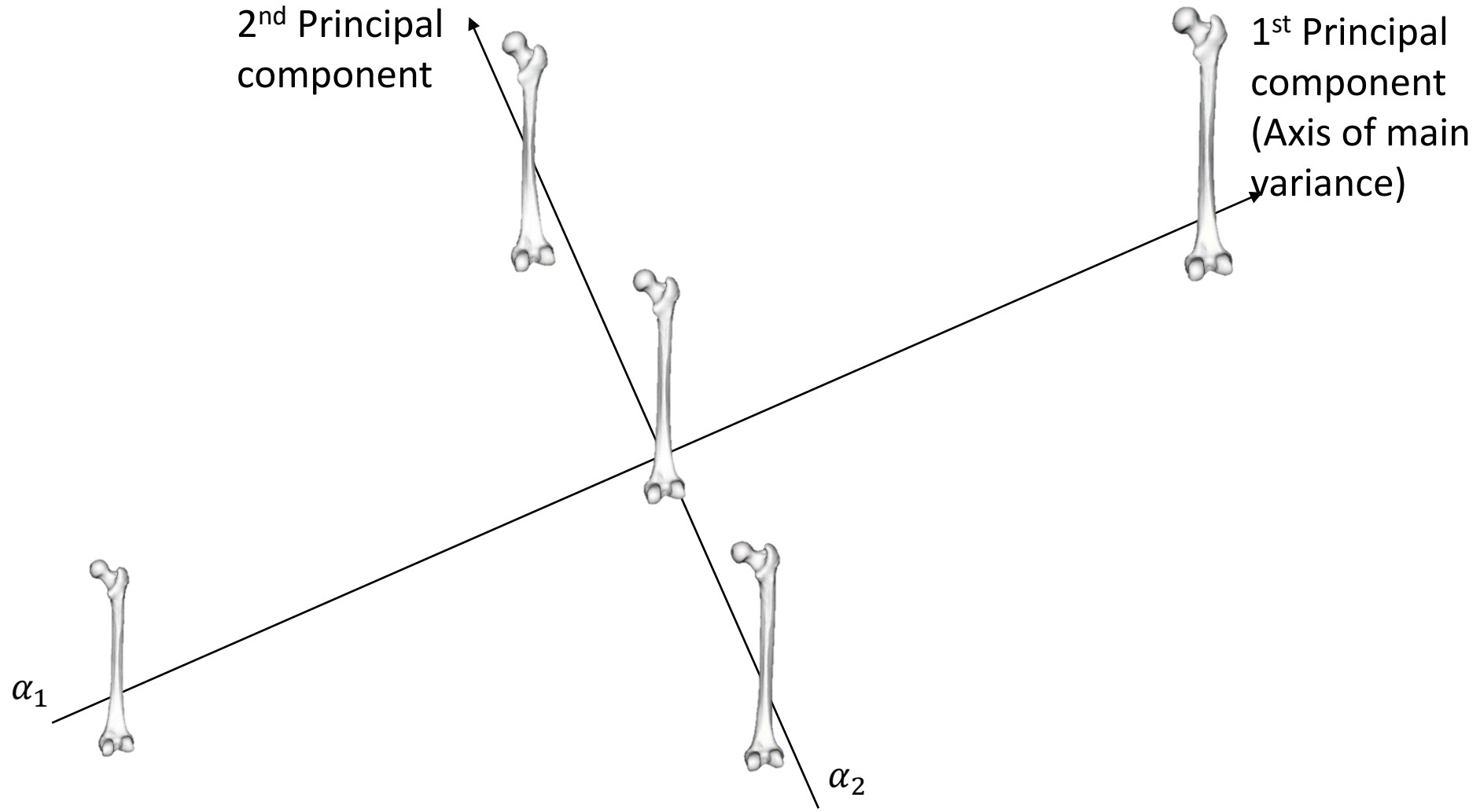
Statistical Shape model: A probability distribution of shapes, learned from example data.

Example shapes

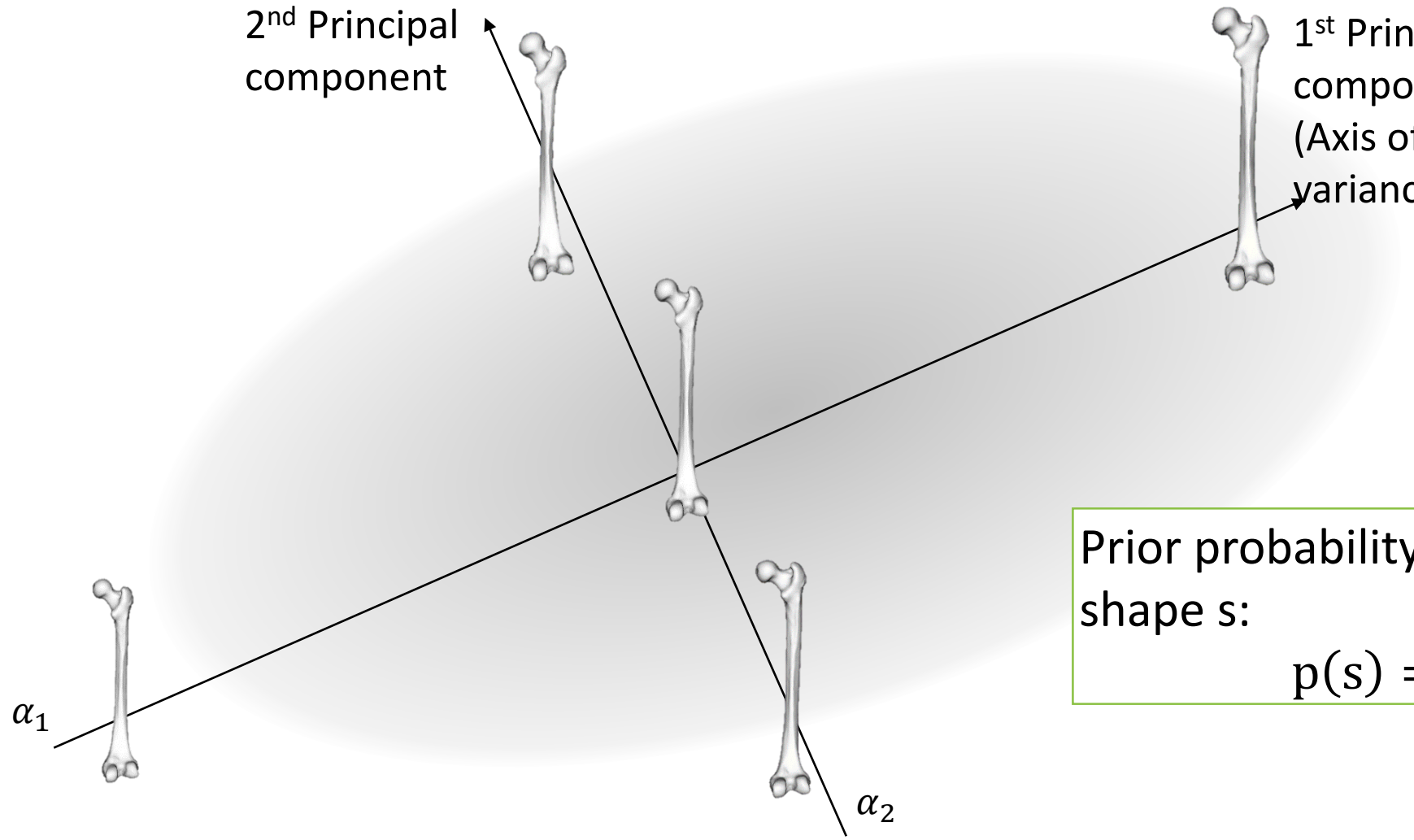




Statistical shape model



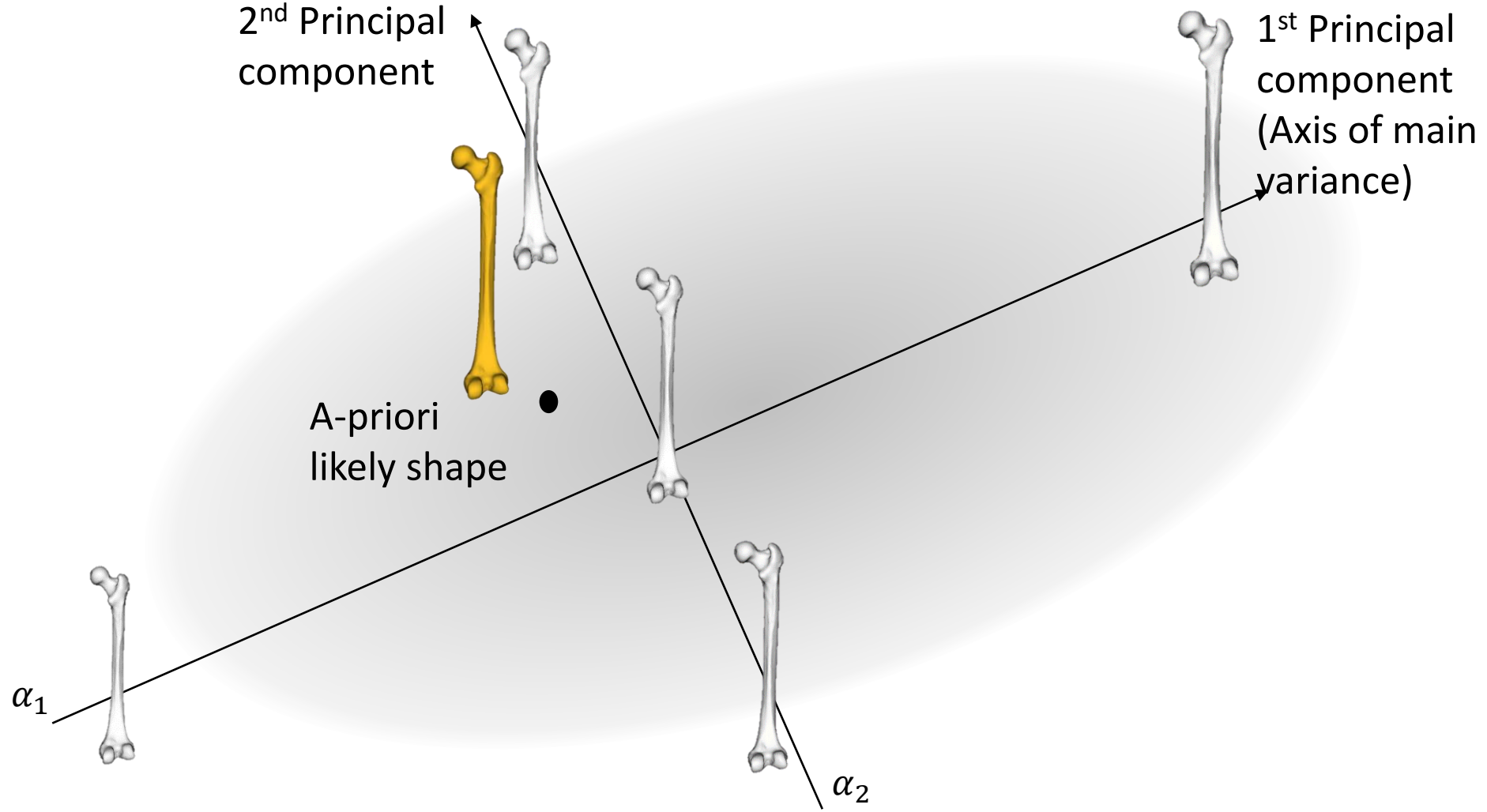
Probability before seeing data



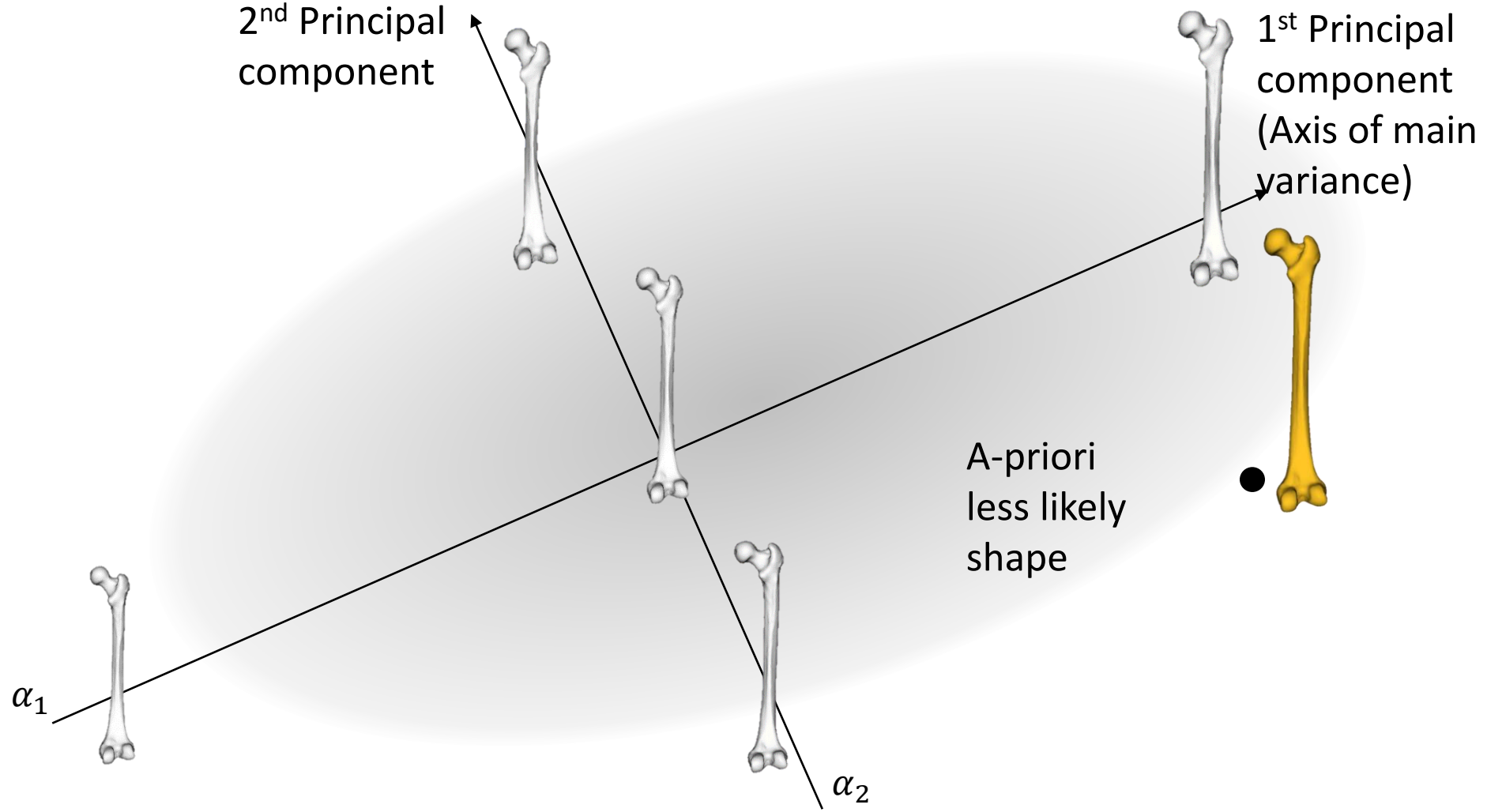
Prior probability of observing shape s:

$$\mathrm{p(s)} = p(\alpha)$$

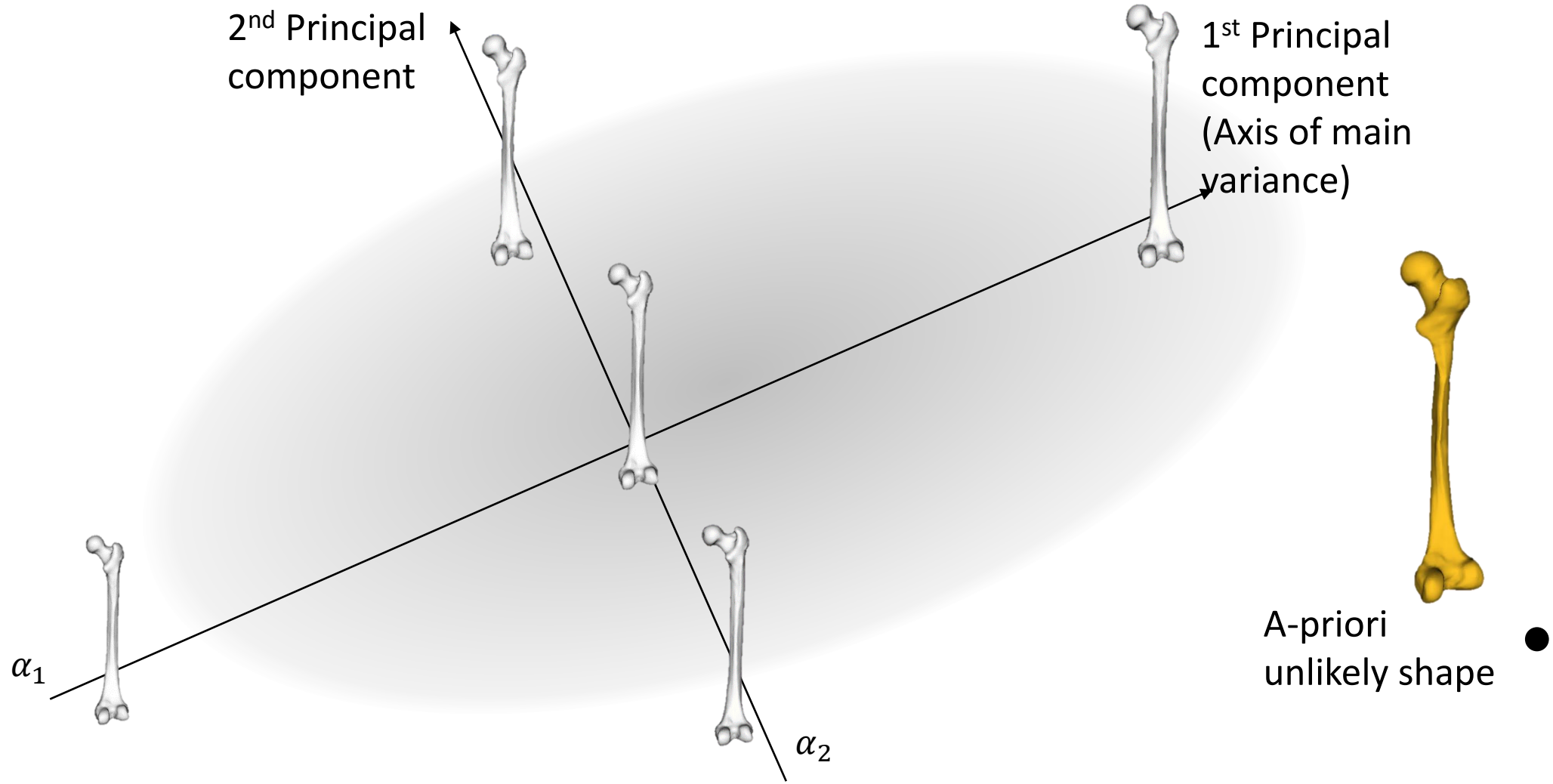
Probability before seeing data



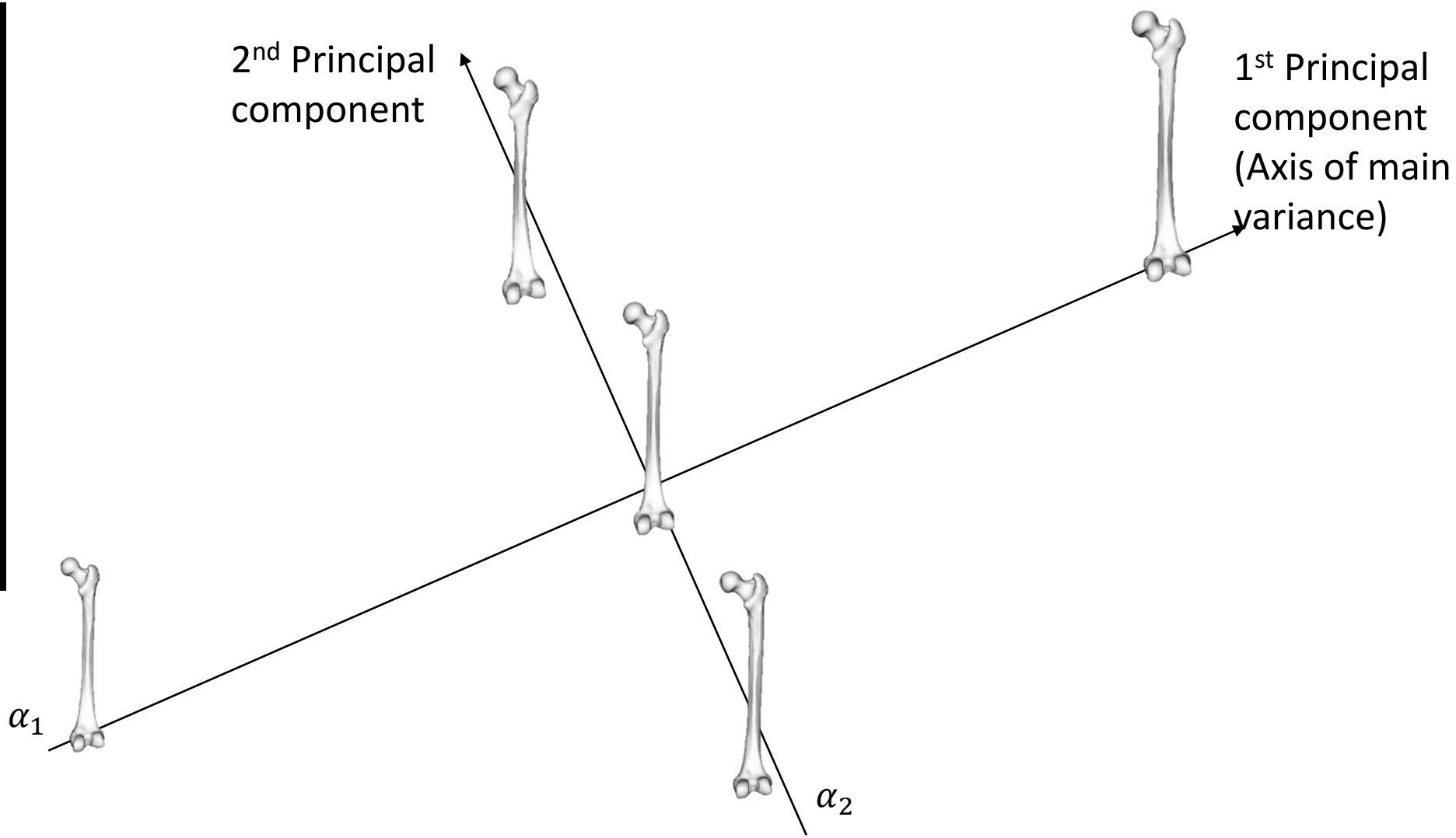
Probability before seeing data



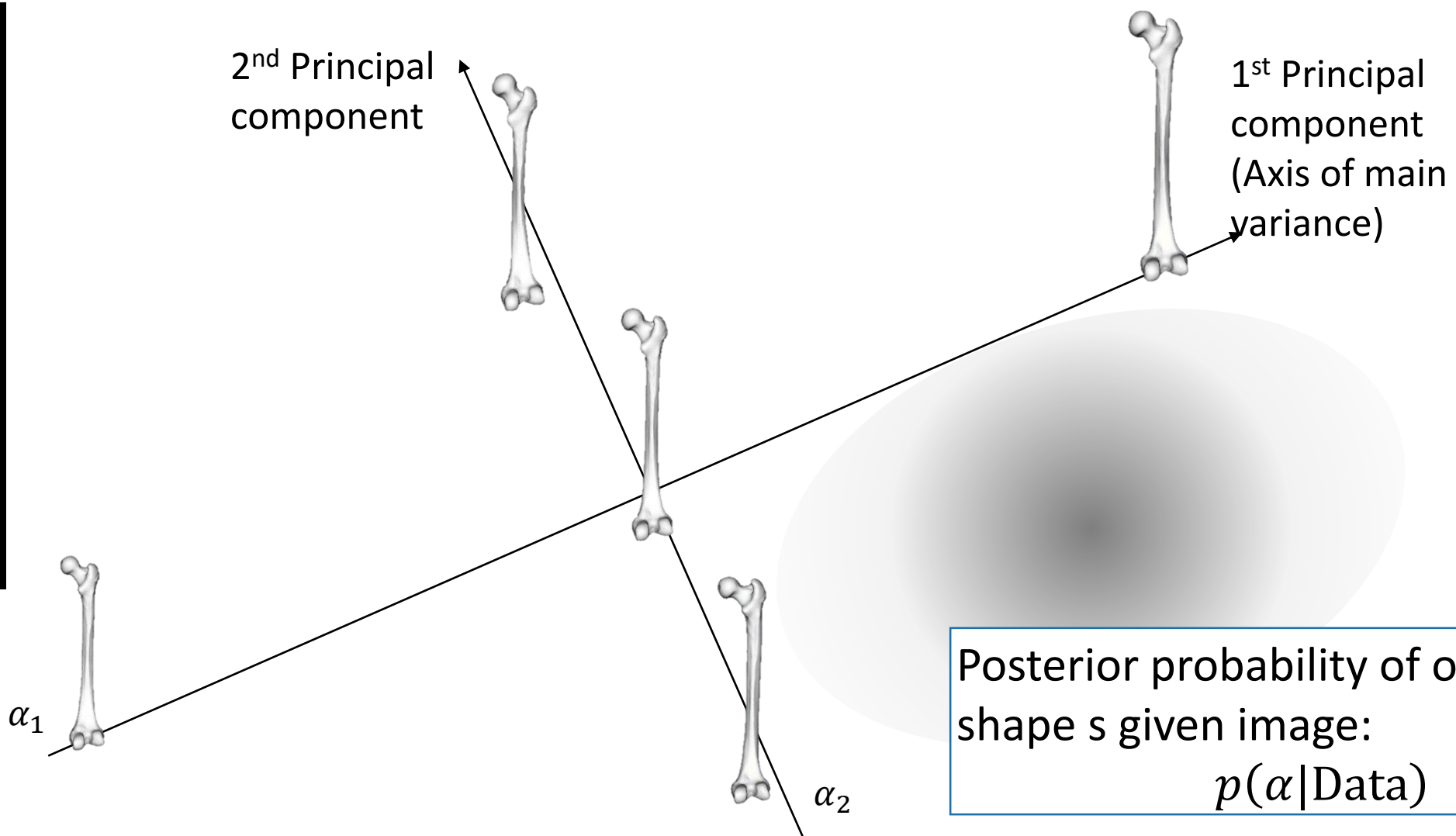
Probability before seeing data



Observing Data



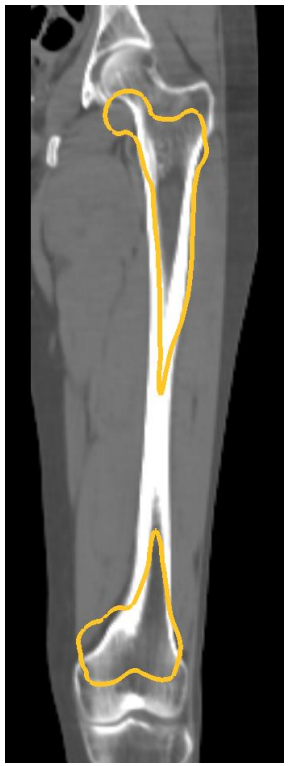
Probability after observing data

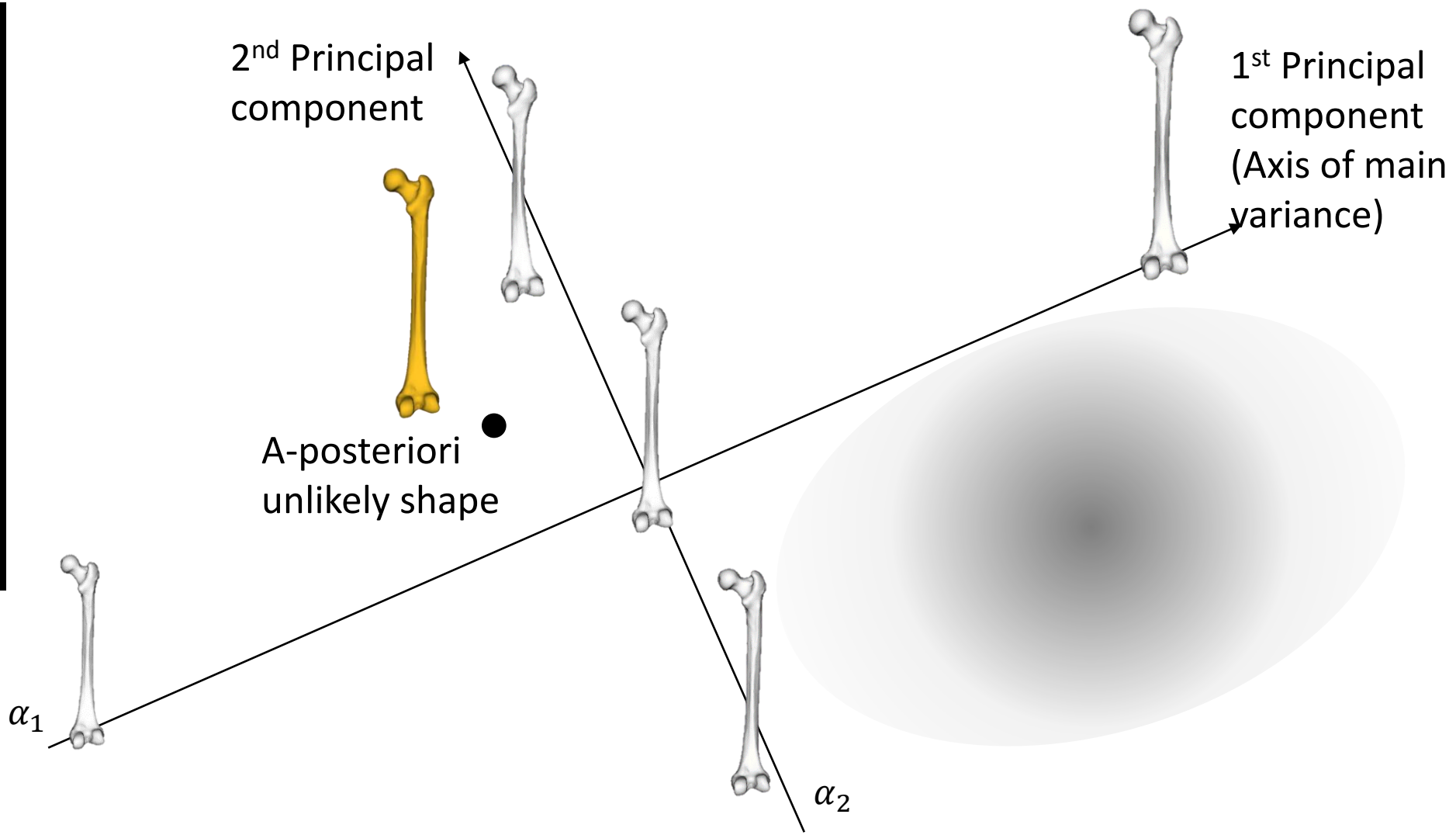


Posterior probability of observing shape s given image:

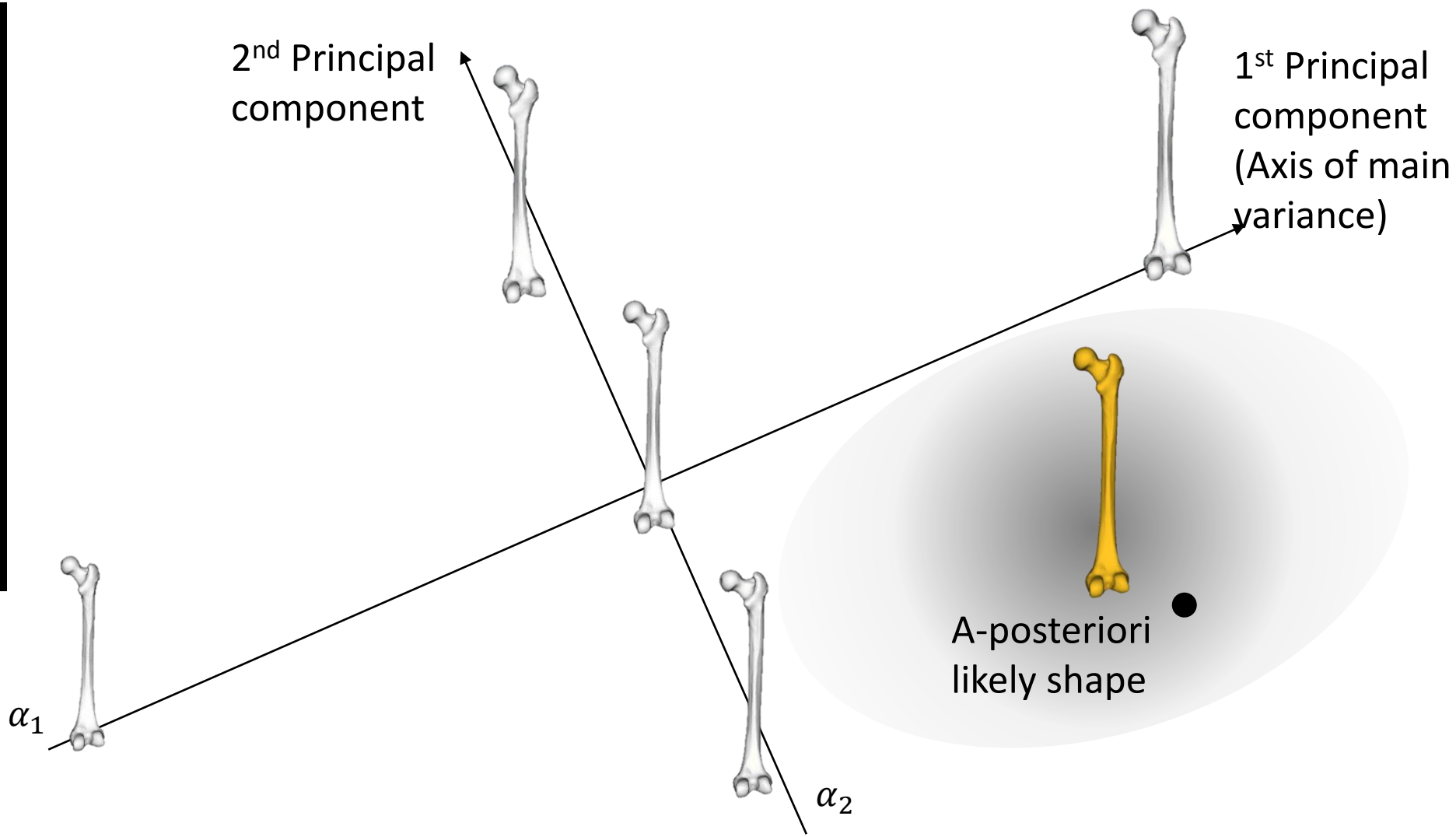
$$p(\alpha|\text{Data})$$

Probability after observing data





Probability after observing data



Model-based data analysis – a Bayesian approach

How well did we explain the data with the model (parameters)

Prior belief: Statistical shape model

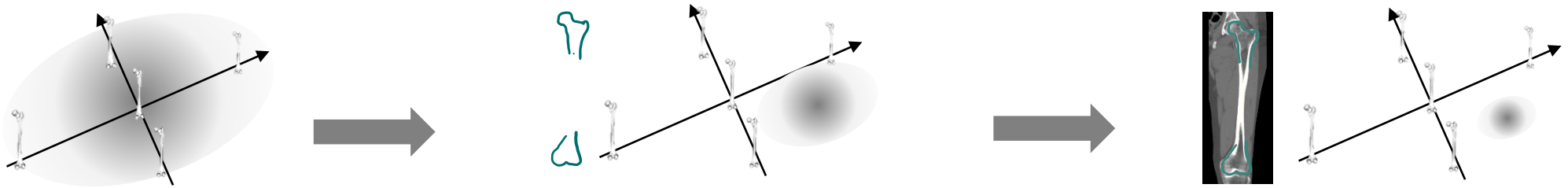
$$P(\alpha|\text{Data}) = \frac{P(\text{Data}|\alpha)P(\alpha)}{P(\text{Data})}$$

Posterior belief

Normalization term (marginal likelihood)

Model-based data– a Bayesian approach

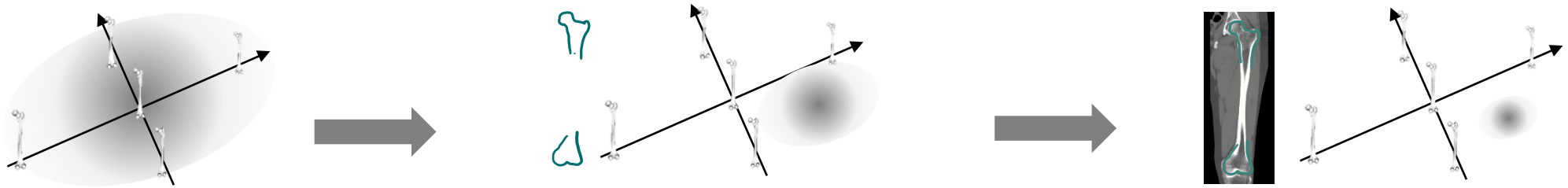
Can introduce new data one by one.



$P(\alpha)$ $P(\alpha|\text{Annotations})$ $P(\alpha|\text{Annotation,Image})$

- Uncertainty is reduced in every step.
- Bayesian inference gives mathematically sound way of updating our knowledge.

Model-based data– a Bayesian approach



$P(\alpha)$ $P(\alpha|\text{Annotations})$ $P(\alpha|\text{Annotation,Image})$

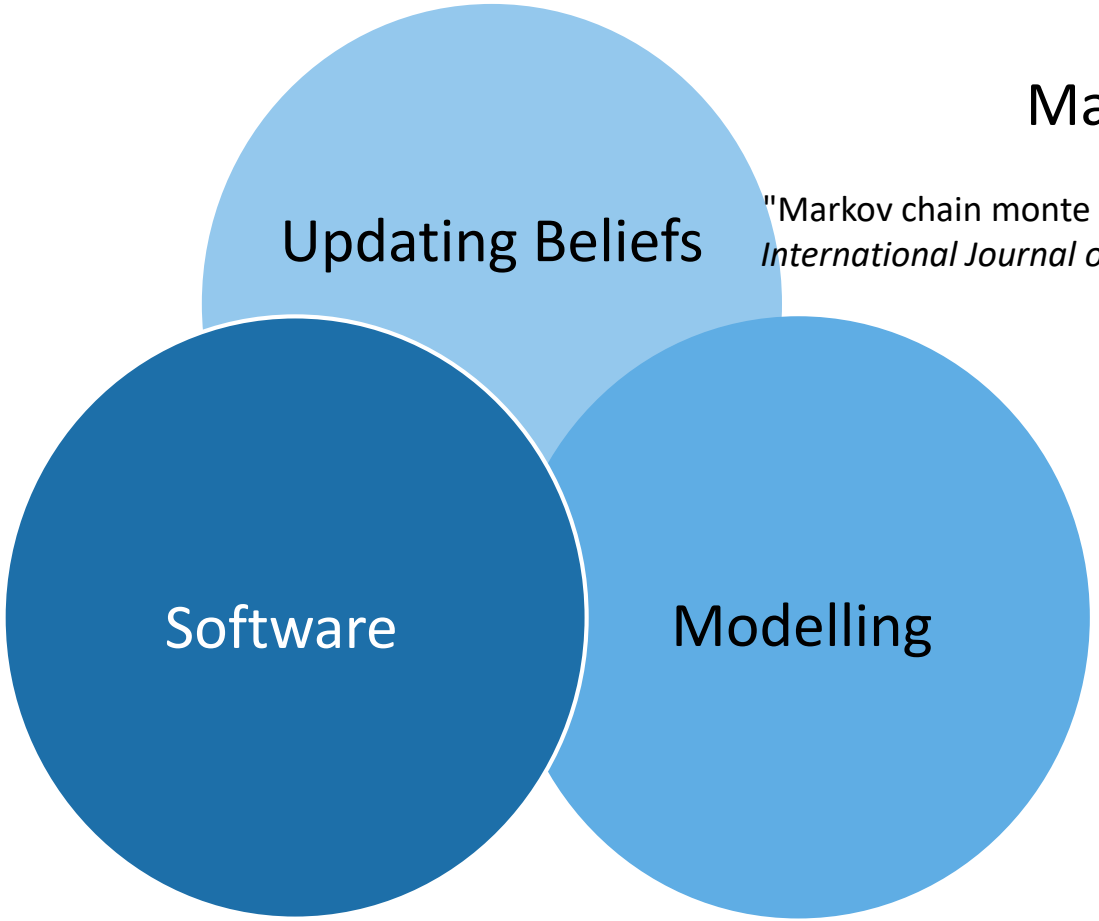
Challenges

- How do we model shape variations?
- How do we update probabilities?
- How do we make this applicable and useful in practice?

Computational problem:

$$P(\alpha|\text{Data}) = \frac{P(\text{Data}|\alpha)P(\alpha)}{\int \dots \int P(\text{Data}|\alpha_1, \dots, \alpha_n)P(\alpha_1, \dots, \alpha_n)d\alpha_1, \dots, d\alpha_n}$$

Probabilistic Shape Modelling



Markov Chain Monte Carlo

Schönborn, Sandro, et al.
"Markov chain monte carlo for automated face image analysis."
International Journal of Computer vision 123.2 (2017): 160-183.

Scalismo

https://github.com/unibas-gravis/scalismo

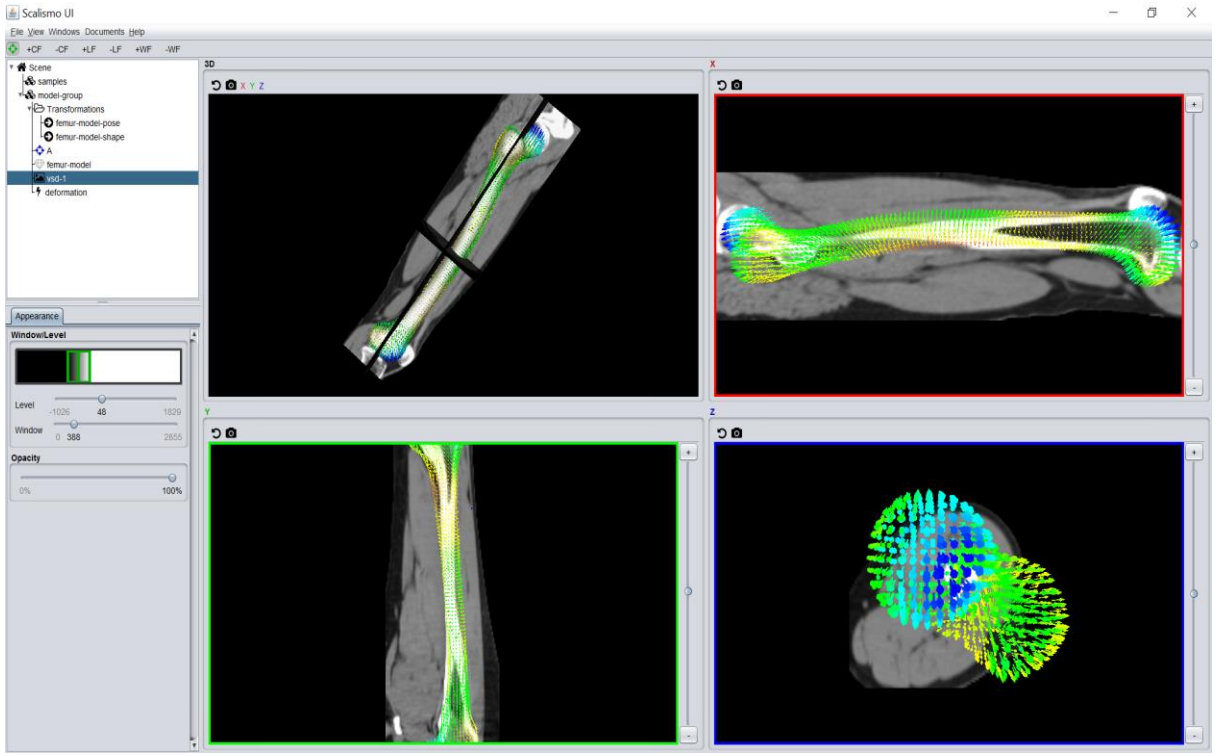
Gaussian processes

Lüthi, Marcel, et al.
"Gaussian process morphable models."
IEEE transactions on pattern analysis and machine intelligence 40.8 (2018): 1860-1873.

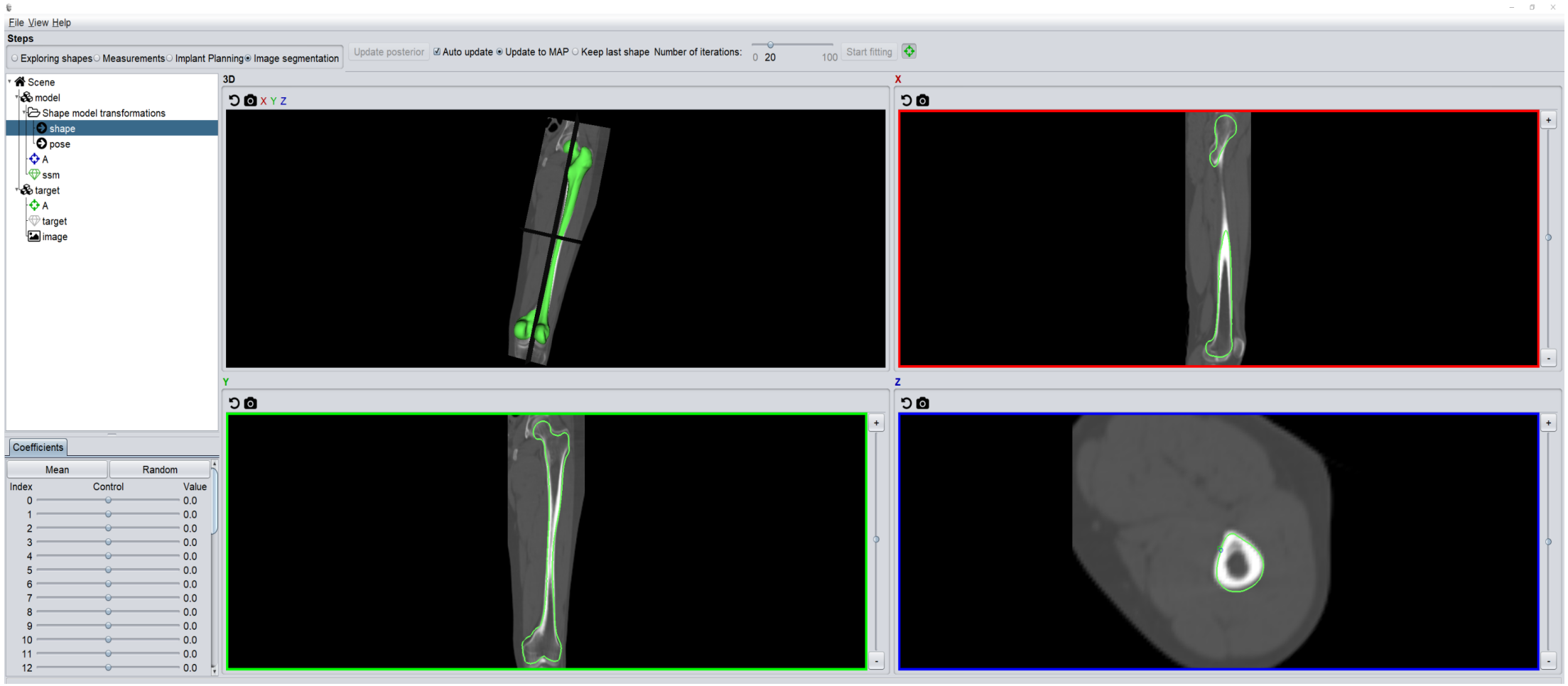
Scalismo

- Open source software for model-based image analysis
- Core concepts:
  - Modelling using Gaussian processes
  - Registration as Model fitting
  - Probabilistic fitting using MCMC
- Strong emphasis on visualization
- Written in Scala

Design goals:
- Easy and efficient to experiment
- Able to scale to professional applications



Demo


File View Help
Steps
Exploring shapes Measurements Implant Planning Image segmentation
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Number of iterations:
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Shape model transformations
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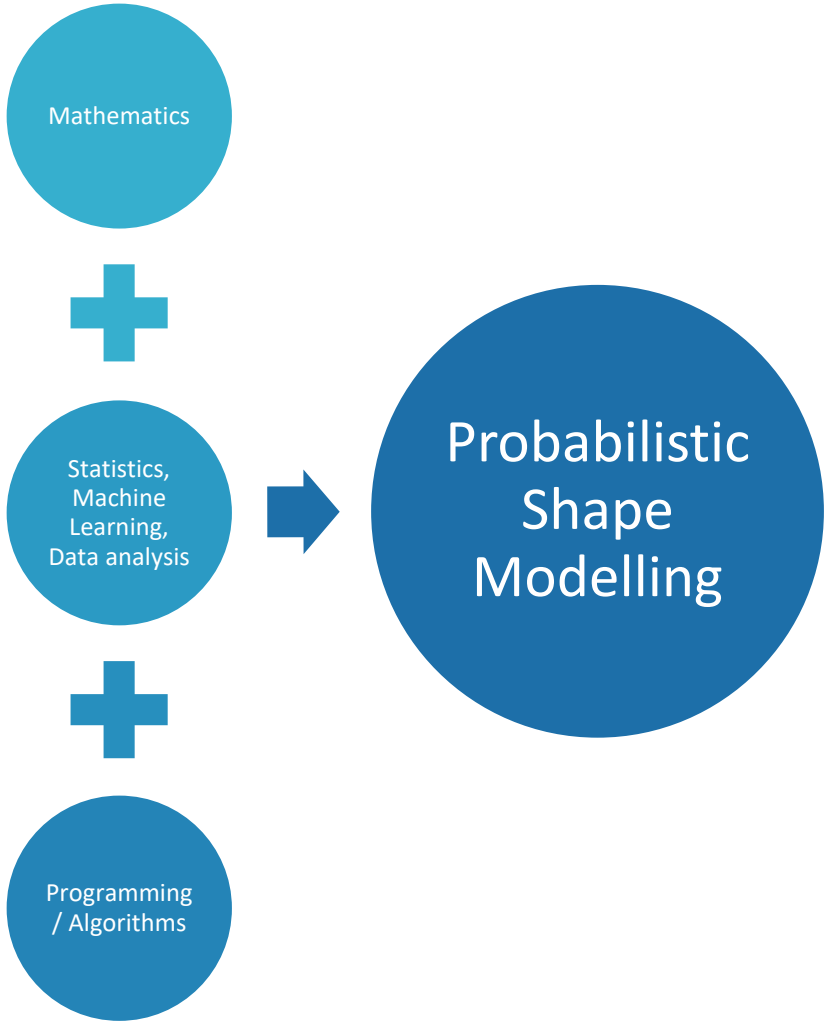
Relationship to other courses / subjects

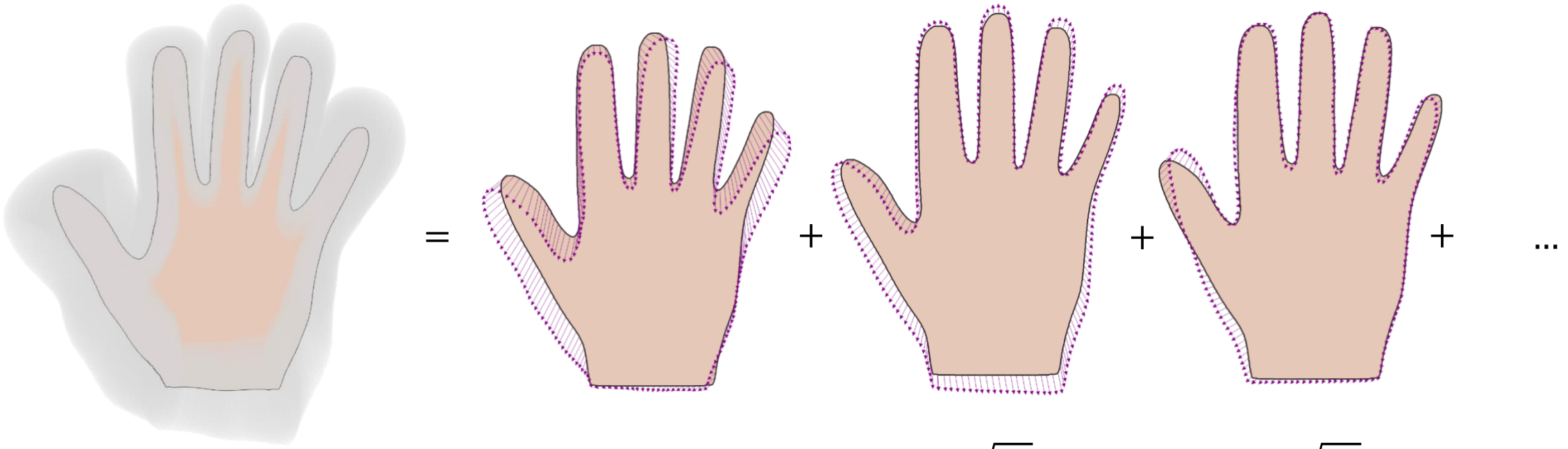


- Gaussian processes
- Markov Chains

- Bayesian inference
- Model fitting
- Markov Chain Monte Carlo

- Implementing systems for image analysis
  - New language: Scala

What you will learn



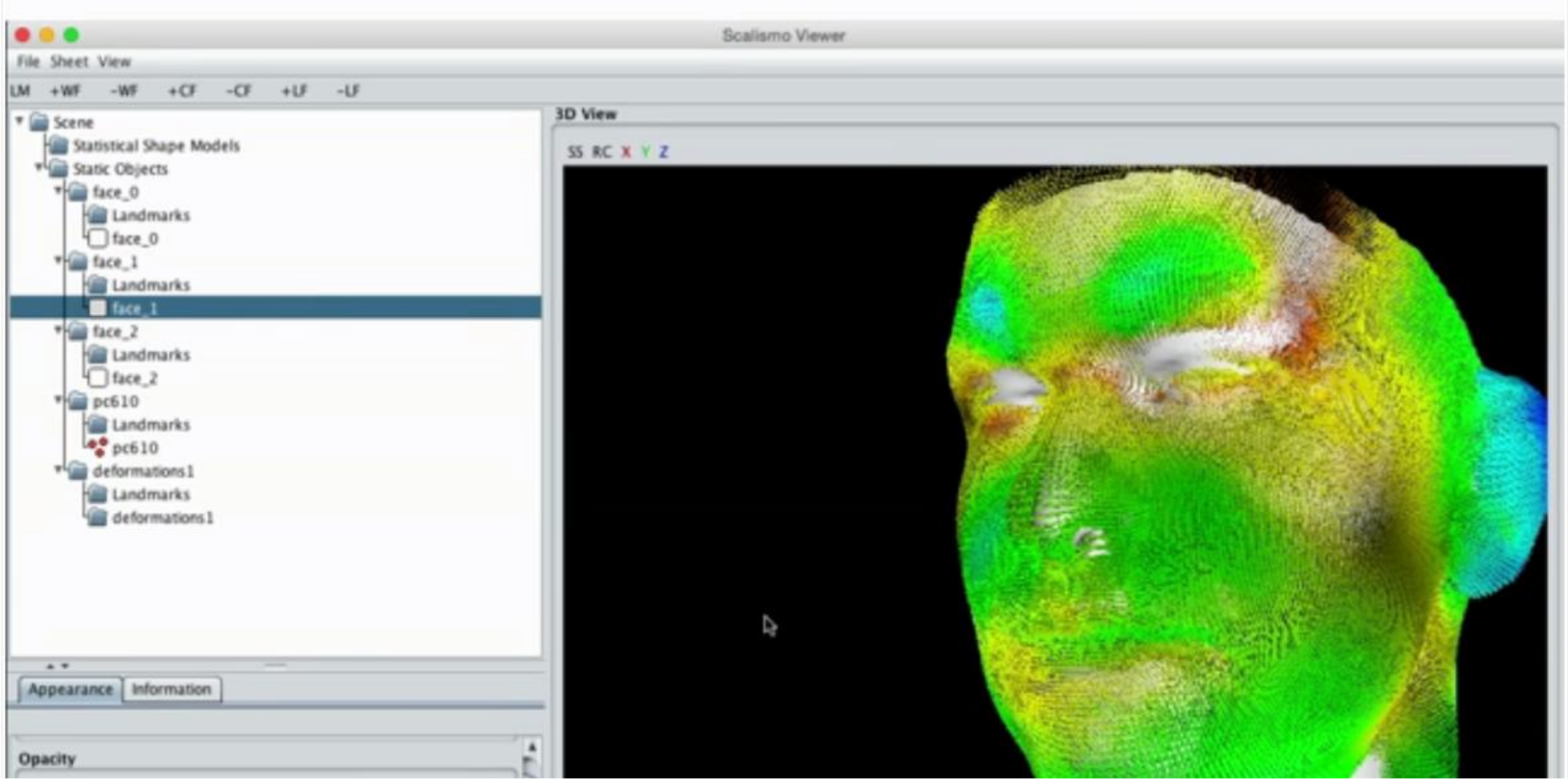
$\tilde{u} \sim GP(\mu, k)$ = μ + $\alpha_1 \sqrt{\lambda_1}\phi_1$ + $\alpha_2 \sqrt{\lambda_2}\phi_2$ + ...

$\alpha_1 \sim N(0,1)$

$\alpha_2 \sim N(0,1)$

- Understanding mathematics visually

What you will learn



- Understanding mathematics through experimentation / programming

What you will learn

- How mathematics can be used to solve real clinical problems!

Course organization

- Basics of shape modelling
- Basics of Gaussian processes
- The scalismo framework

- Model-based image analysis
- Markov Chain Monte Carlo
- Face image analysis

Online course (MOOC):
Shape Modelling

Traditional lectures:
Model fitting

What is a MOOC?

Massive Open Online Course (MOOC)

- Illustration Till Hafenbrak

Massive: There is no limitation on the number of participants

Open: Everybody can access free of charge, independent of age / educational background. No formal enrollment procedure.

Online: It Is fully offered via the internet

Course: It is offered during a fixed period of time, where also mentoring/assistance is provided.

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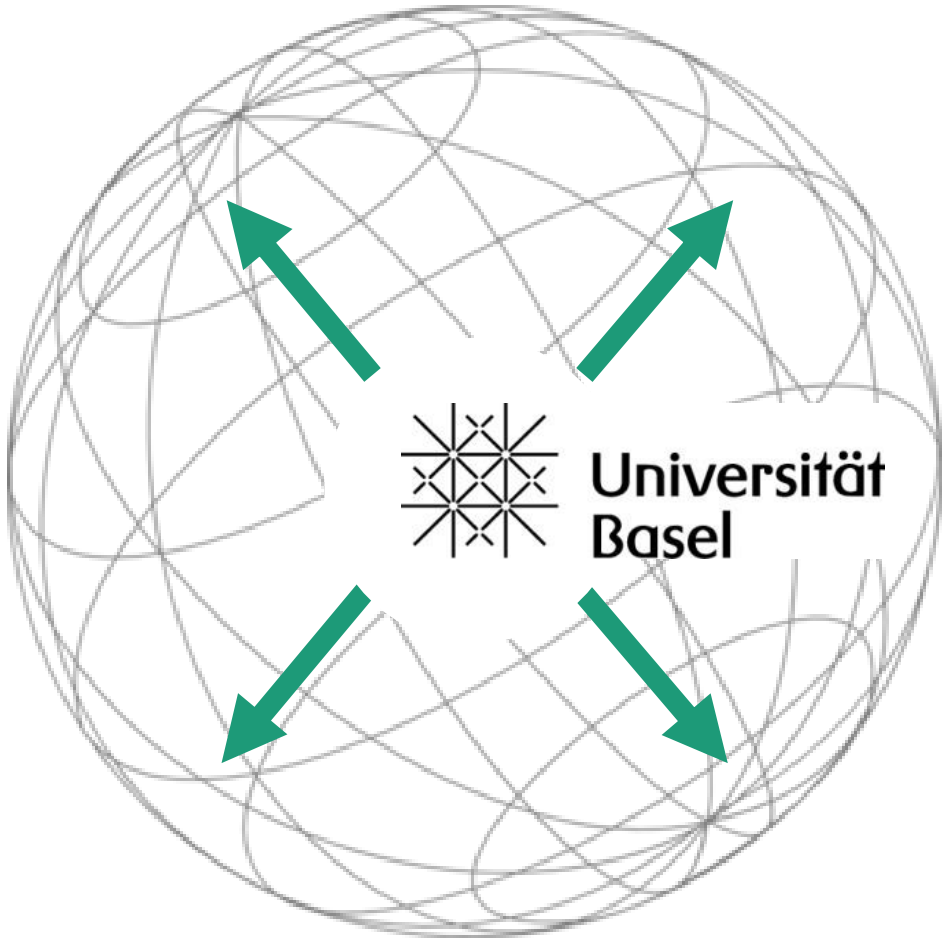
Goal 1: Internationalisation



- Marketing instrument for the university
- Focus on research areas of international interest
- Enhance visibility and teaching excellence in these areas.

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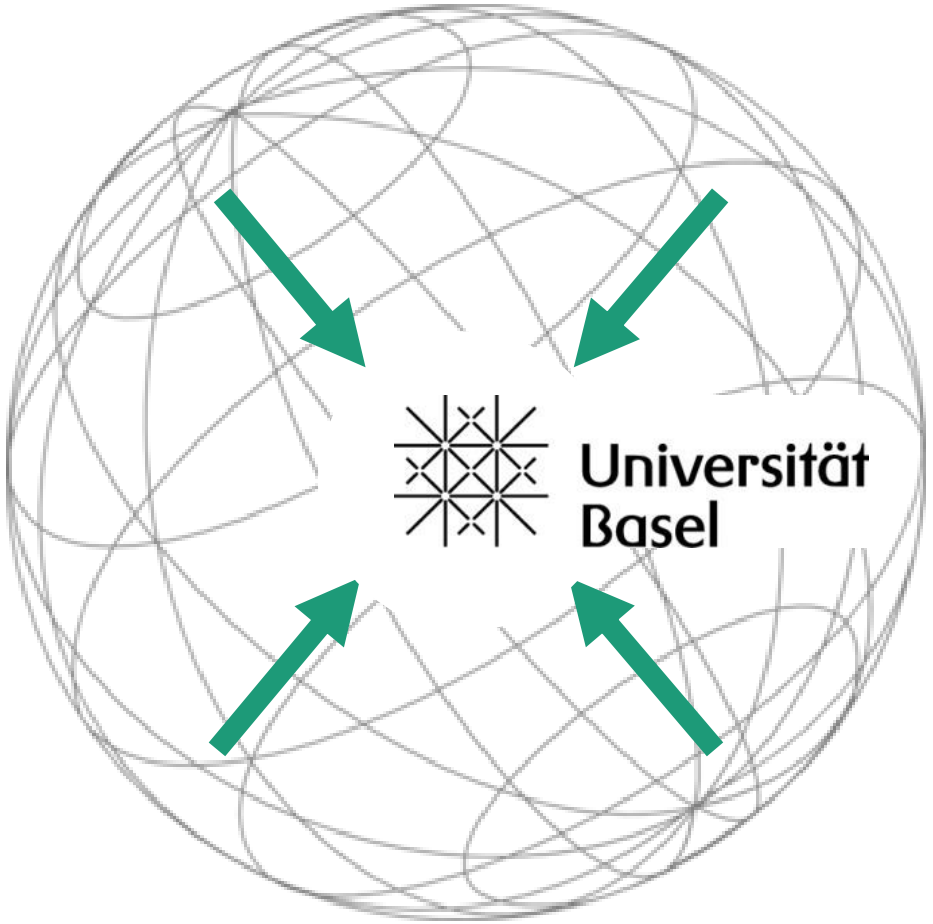
Goal 2: Teaching innovation



- Benefits students from University of Basel
- Research oriented education in an international context
- Strengthening of the «Campus Basel» through complementary digital course offerings.

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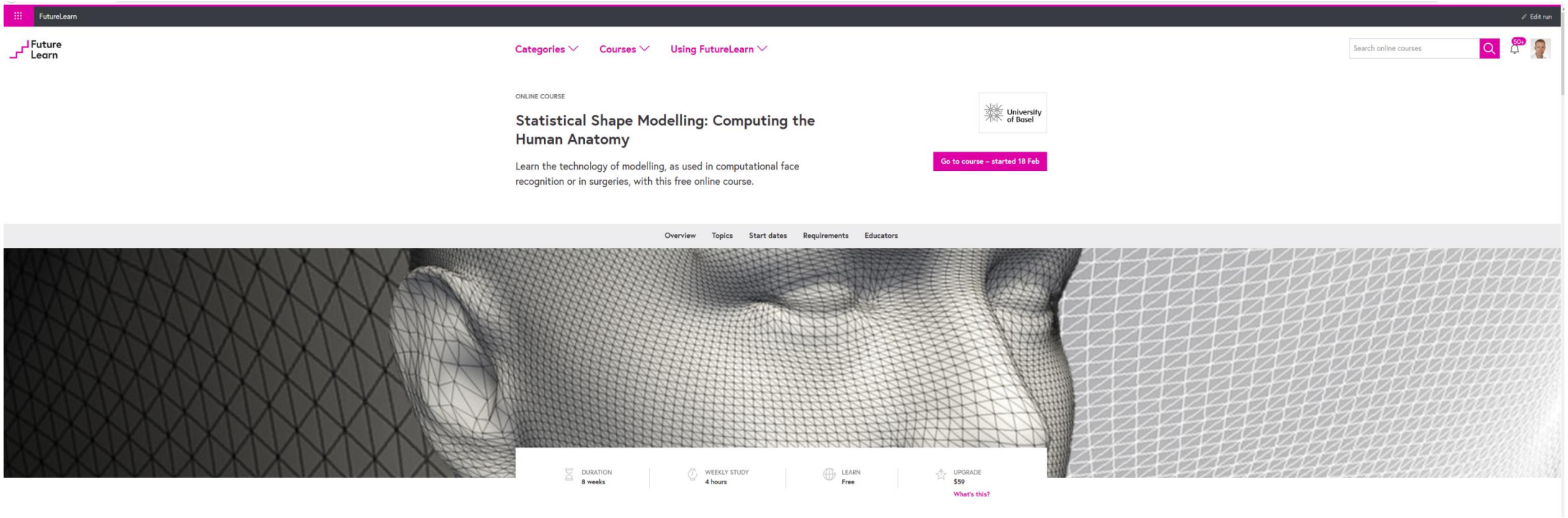
Your MOOC


FutureLearn
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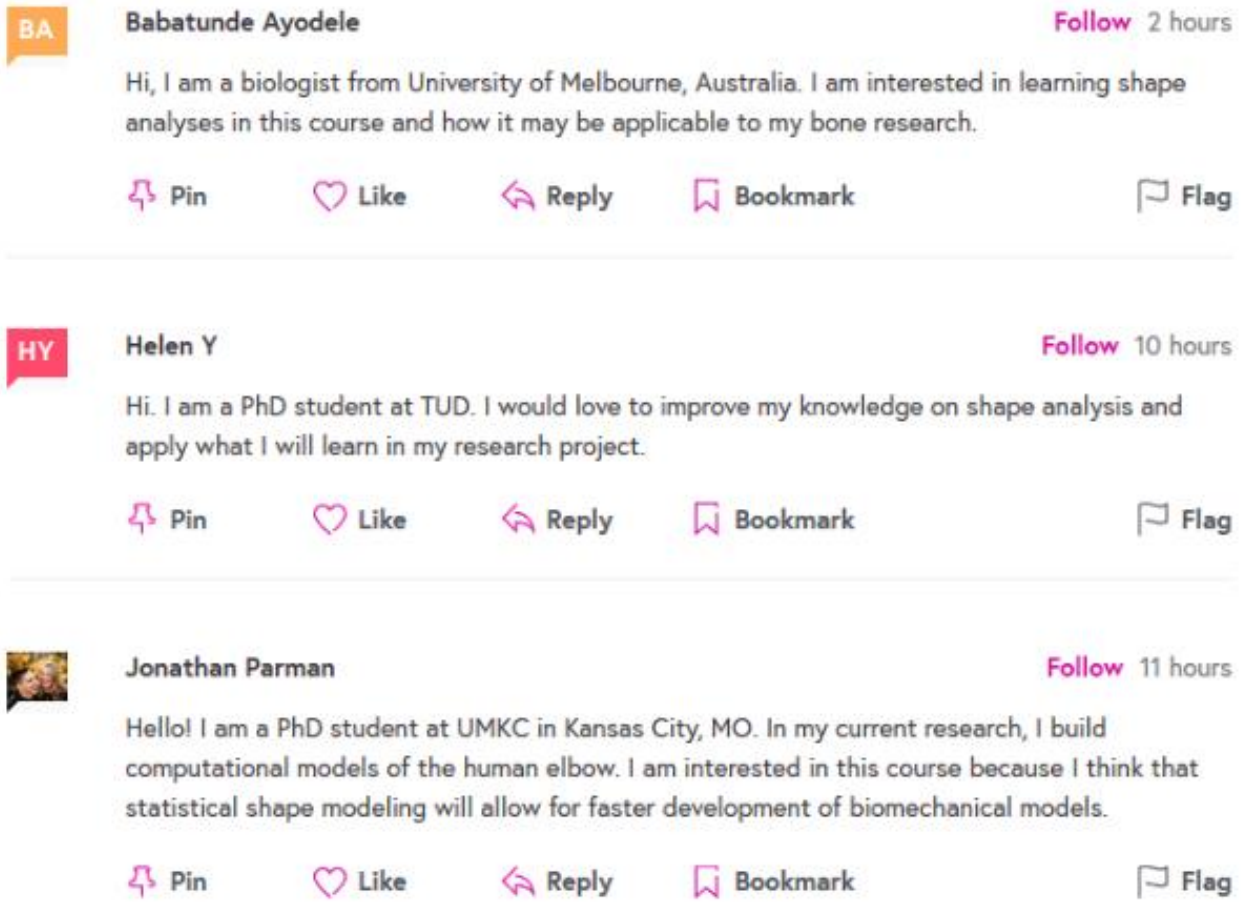
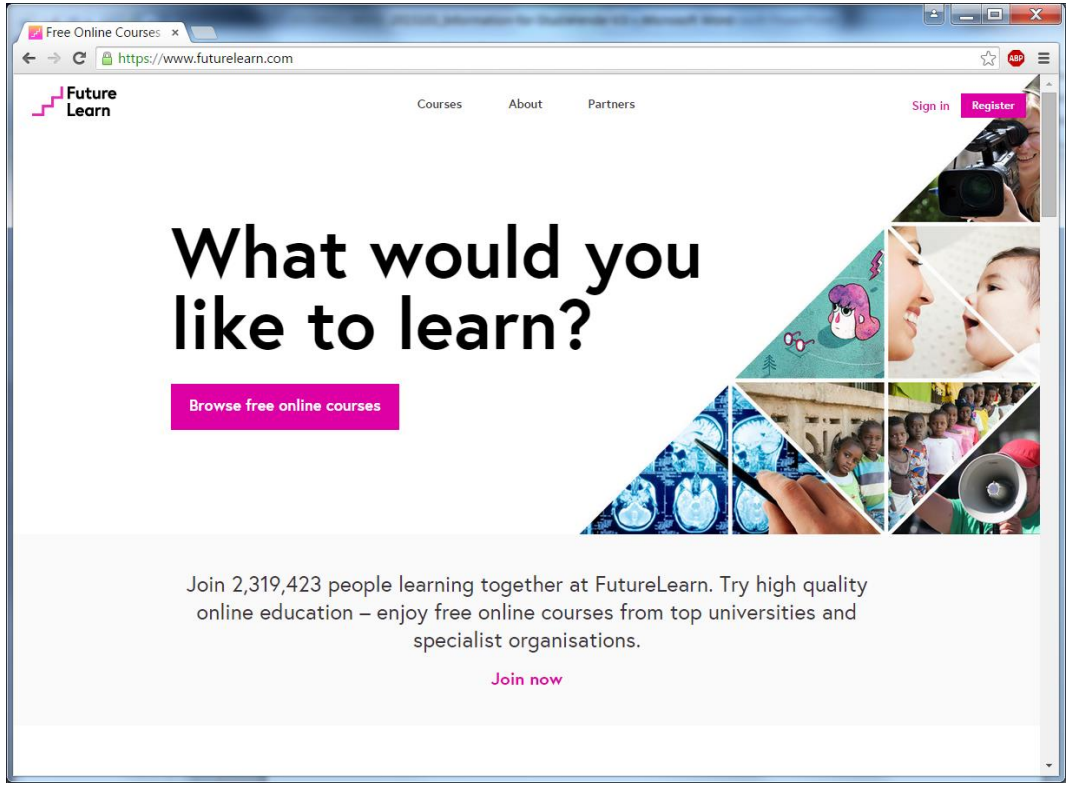
ONLINE COURSE
Statistical Shape Modelling: Computing the Human Anatomy
Learn the technology of modelling, as used in computational face recognition or in surgeries, with this free online course.
University of Basel
Go to course – started 18 Feb
Overview
Topics
Start dates
Requirements
Educators
DURATION
8 weeks
WEEKLY STUDY
4 hours
LEARN
Free
UPGRADE
$59
What's this?

Studying with international peers



MOOC Platform: FutureLearn



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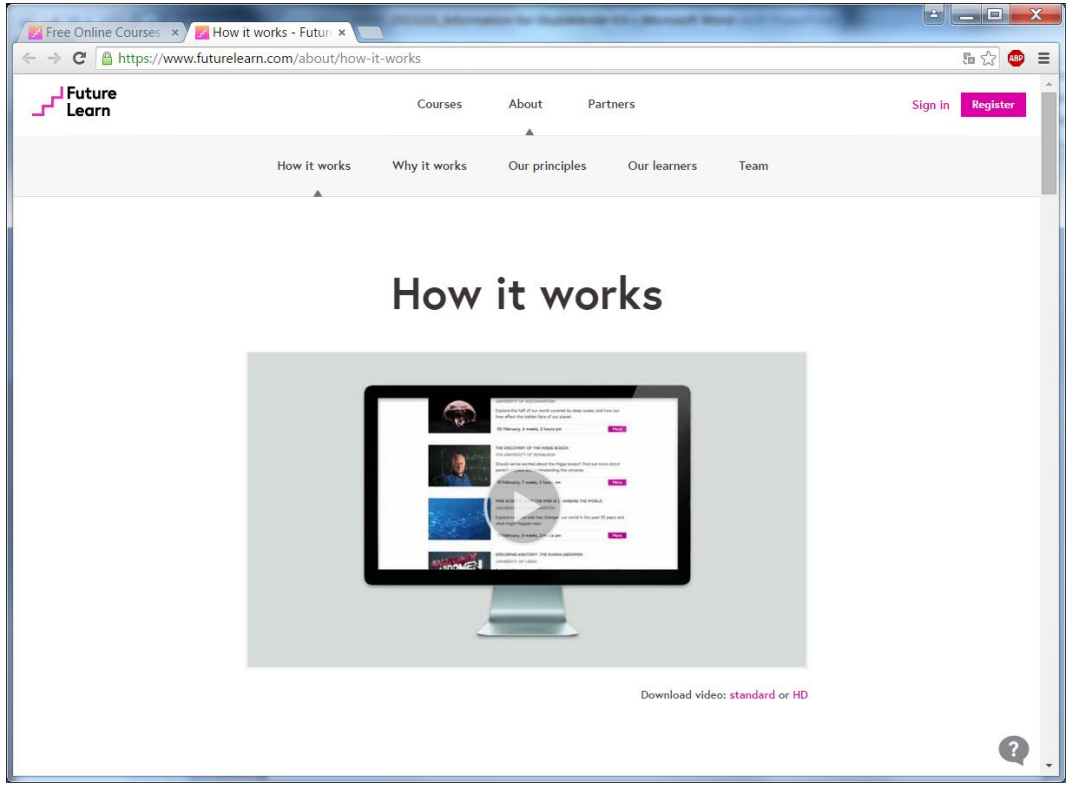
How does FutureLearn work?



https://www.futurelearn.com/about/how-it-works

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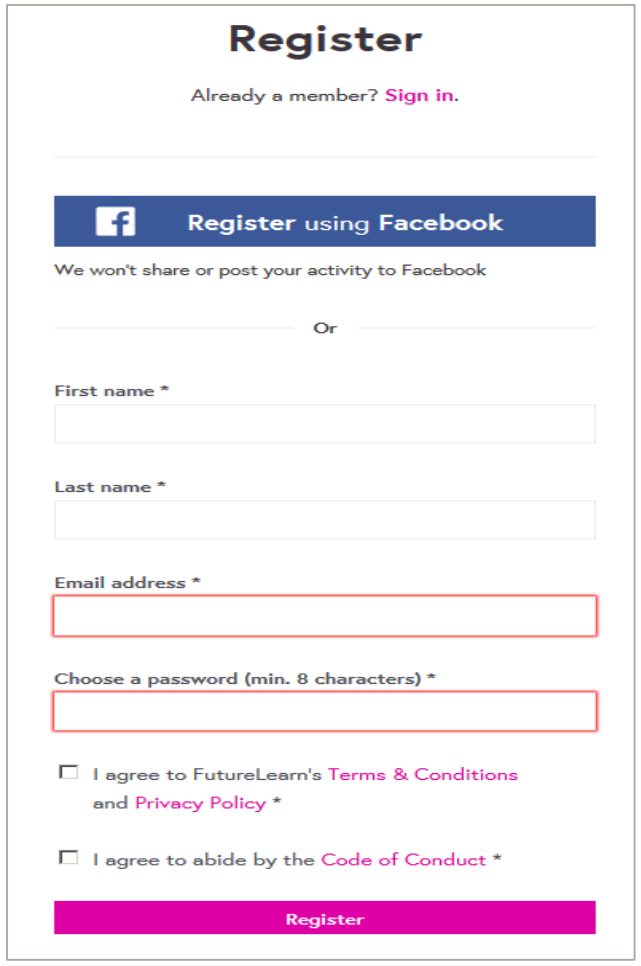
How to register on FutureLearn



You need to provide

- First name / Last name
- email address
- Password

Do not use your university password!

You need to agree to the

- Terms and conditions
- Privacy policy
- **Code of Conduct**

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Your identity on FutureLearn

FutureLearn asks you to

- create only one account
- use your real name

You must not

- share the account with anybody else
- falsely state, impersonate, misrepresent your identity,

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Using generated content

- Learnes generate own content (profile pages, comments, etc)
- **FutureLearn does not own user generated content**
  - Content is licenced under a Creative-Commons-Licence BY-NC-MD

- Be aware that **content is accessible worldwide, unlimited and free of charge**.
- By agreeing to the terms and condition you guarantee that you created the content yourself.

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Data protection

- Data protection and privacy is important for Future Learn and the University of Basel.
  - FutureLearn is a British company and falls under the EU law.
- The data protection policy lists which information FutureLearn is collecting and what this information can be used for.

https://about.futurelearn.com/terms/data-protection-policy/

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Embedding of the MOOC into this course

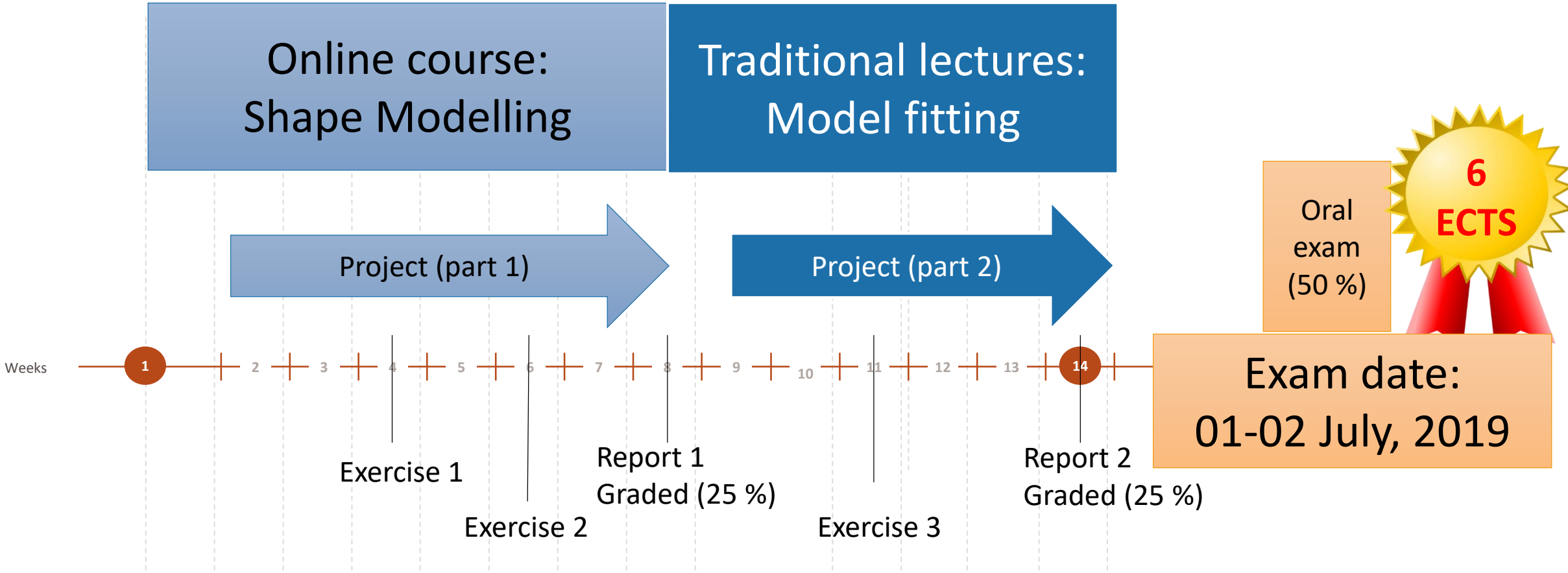
- We do not check if you follow the course, but
  - it is a mandatory part of the lecture
  - you will be asked about the theory taught in the course in the oral exams
- The University of Basel will not and cannot access data of individual learners.
- There is no data exchange between the study administration of the University of Basel and FutureLearn.

How to get the credit points

- FutureLearn does not award any credit points.
- The FutureLearn certificate does not translate into ECTS points.

- You don’t need to buy the Statement of Participation (unless you want to support FutureLearn)
- You don’t need to upgrade the course to access the material

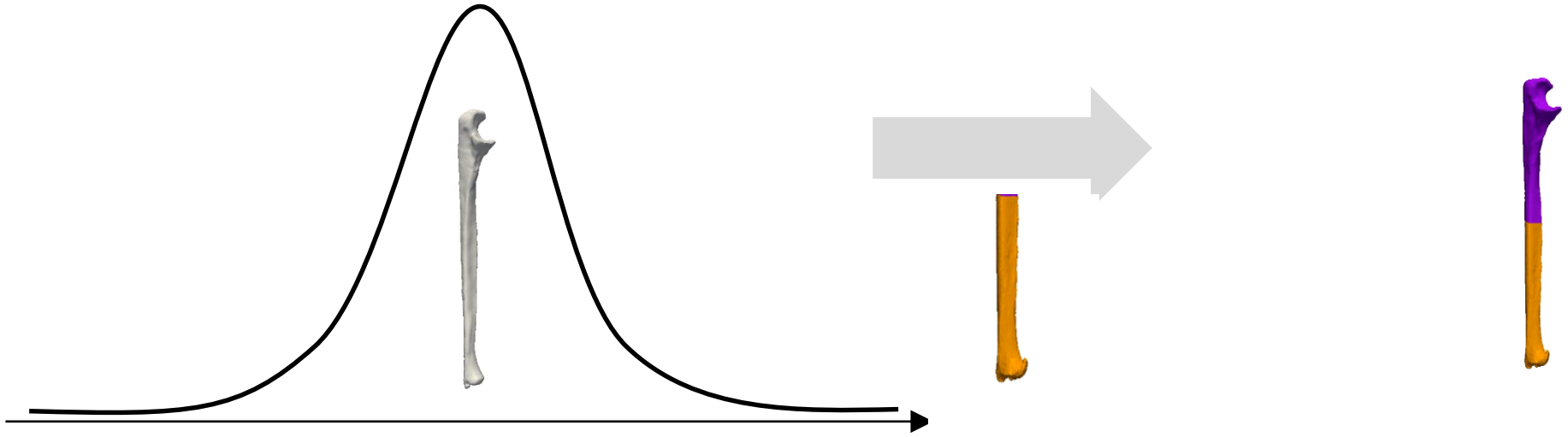
How to get the credit points



- Exercises (in groups of 2) need to be presented during exercise sessions

Project 1: Shape reconstruction

- Challenge: Find best reconstruction for partial femur
  - Compete with researchers from all over the world



Project 2: Segment a bone from an image

Next stop: Futurelearn

ONLINE COURSE

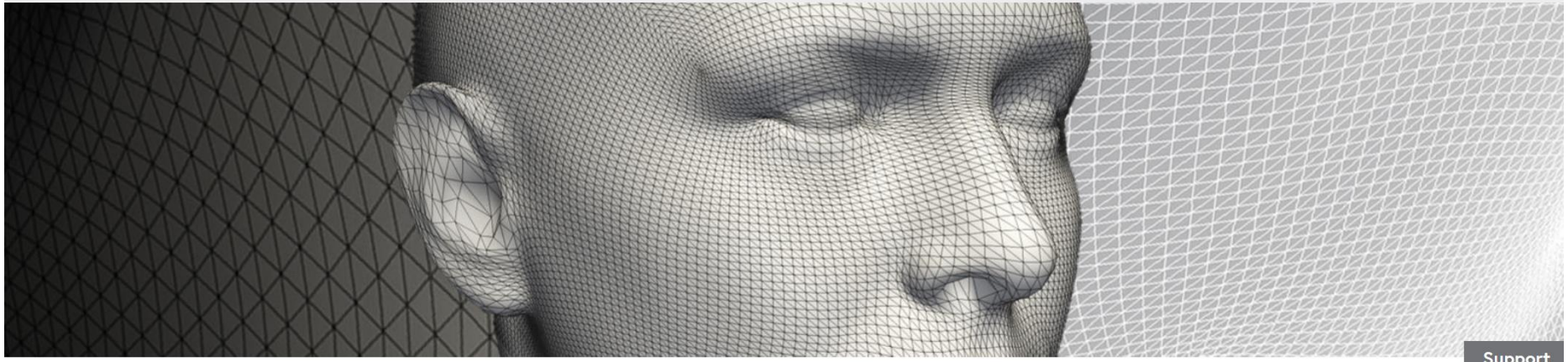
Statistical Shape Modelling: Computing the Human Anatomy

Learn the technology of modelling, as used in computational face recognition or in surgeries, with this free online course.

University of Basel

Join course

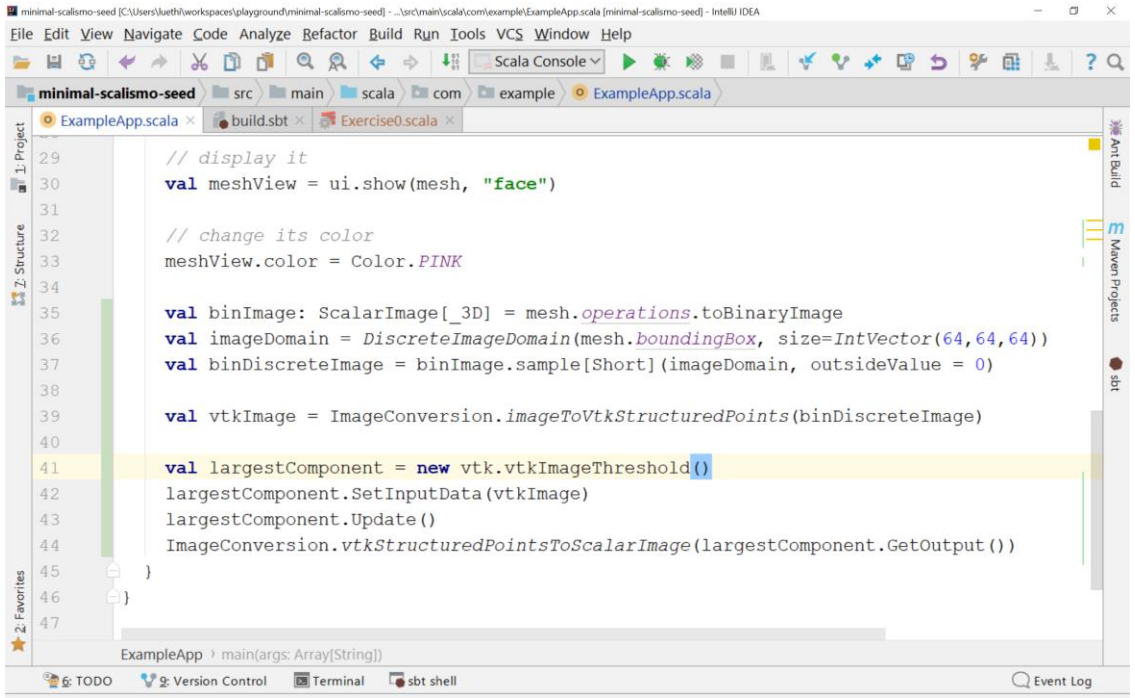
Overview Topics Start dates Requirements Educators



https://www.futurelearn.com/courses/statistical-shape-modelling

Our next meeting

- Introduction to the exercises and project
- Tutorial: How to work with Scala
  - Setting up Scalismo in an IDE
  - Basics of Scala
- Questions & Answer



- Please bring your computer!

Tuesday, 26. February, 14.15 – 16.00