# Probabilistic Morphable Models
# - An overview -

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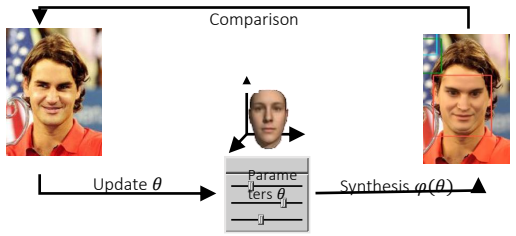
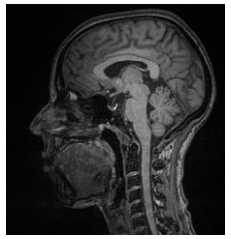
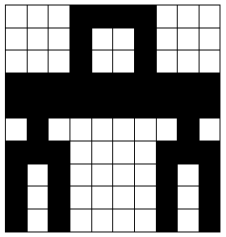
# Outline




Analysis by synthesis



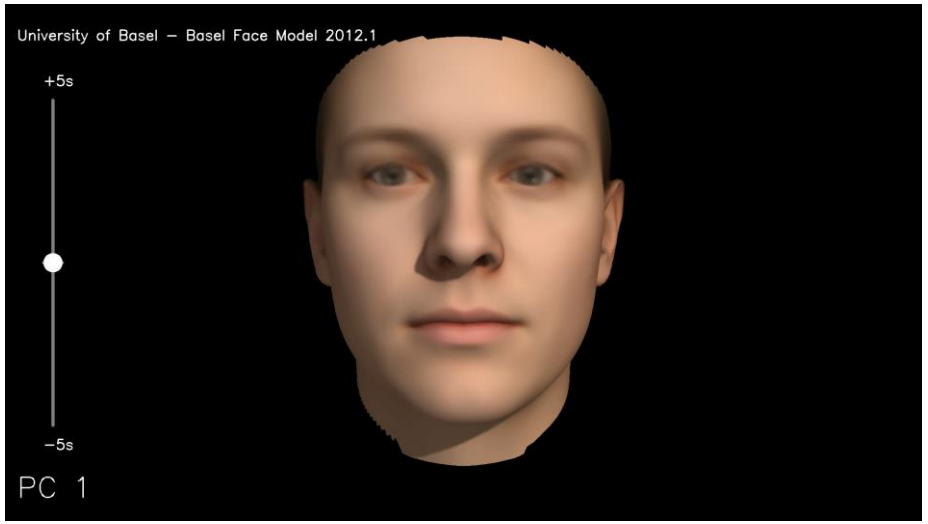
Medical image analysis verse computer vision



The space of images

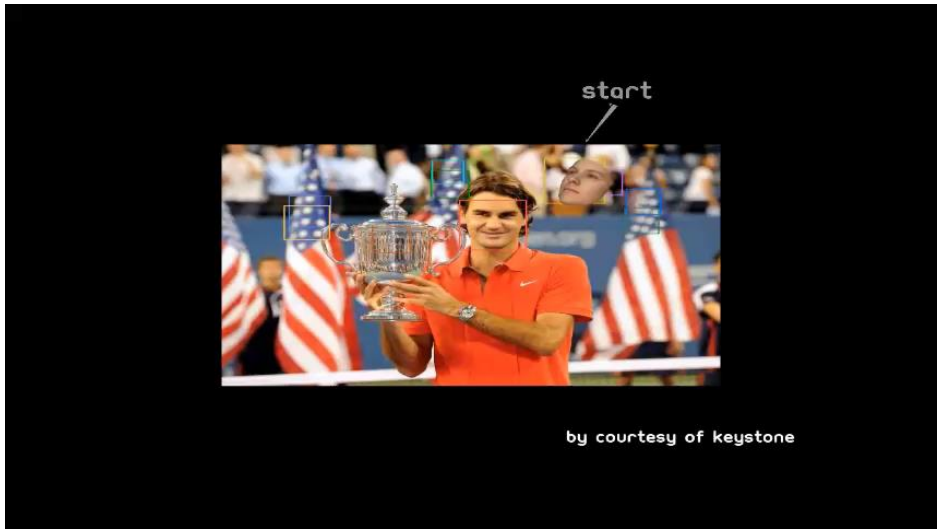
# Probabilistic Morphable Models

Online Course




Shape Modelling

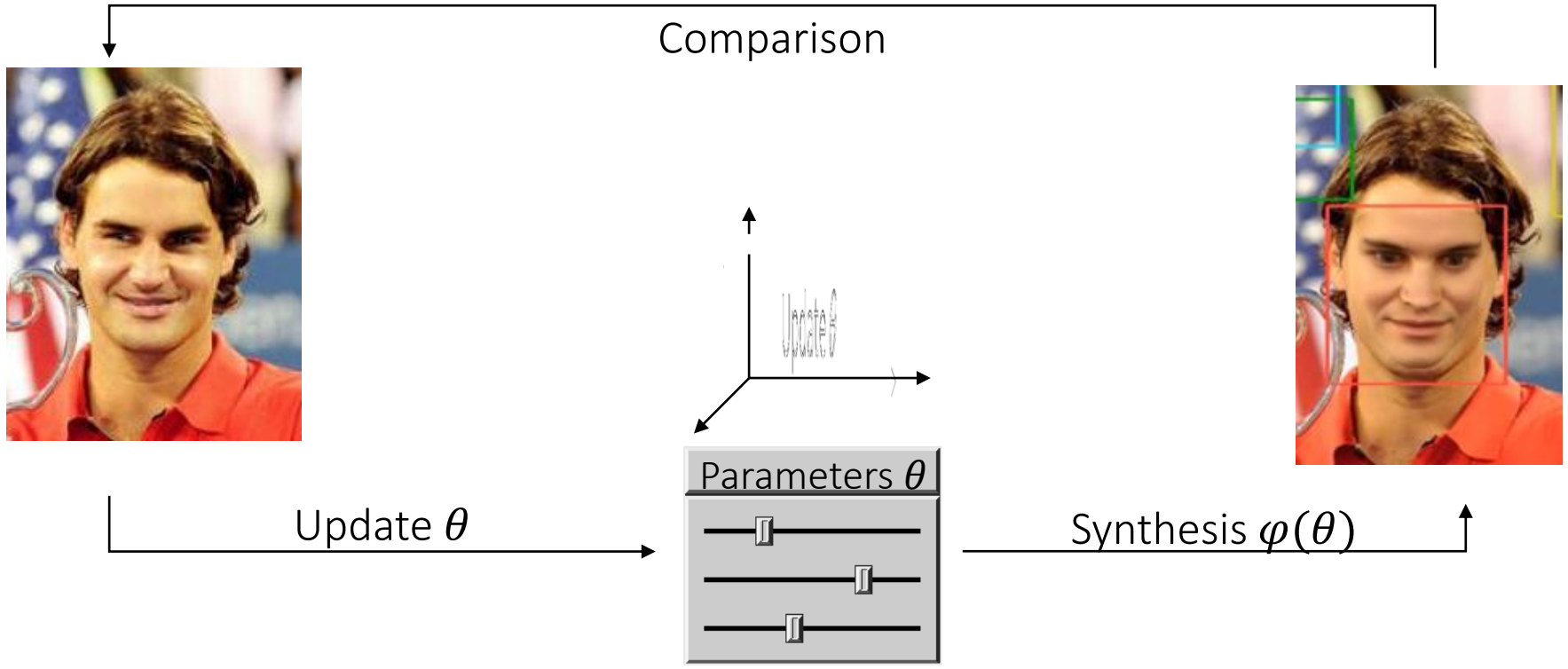
Summer school




Model fitting

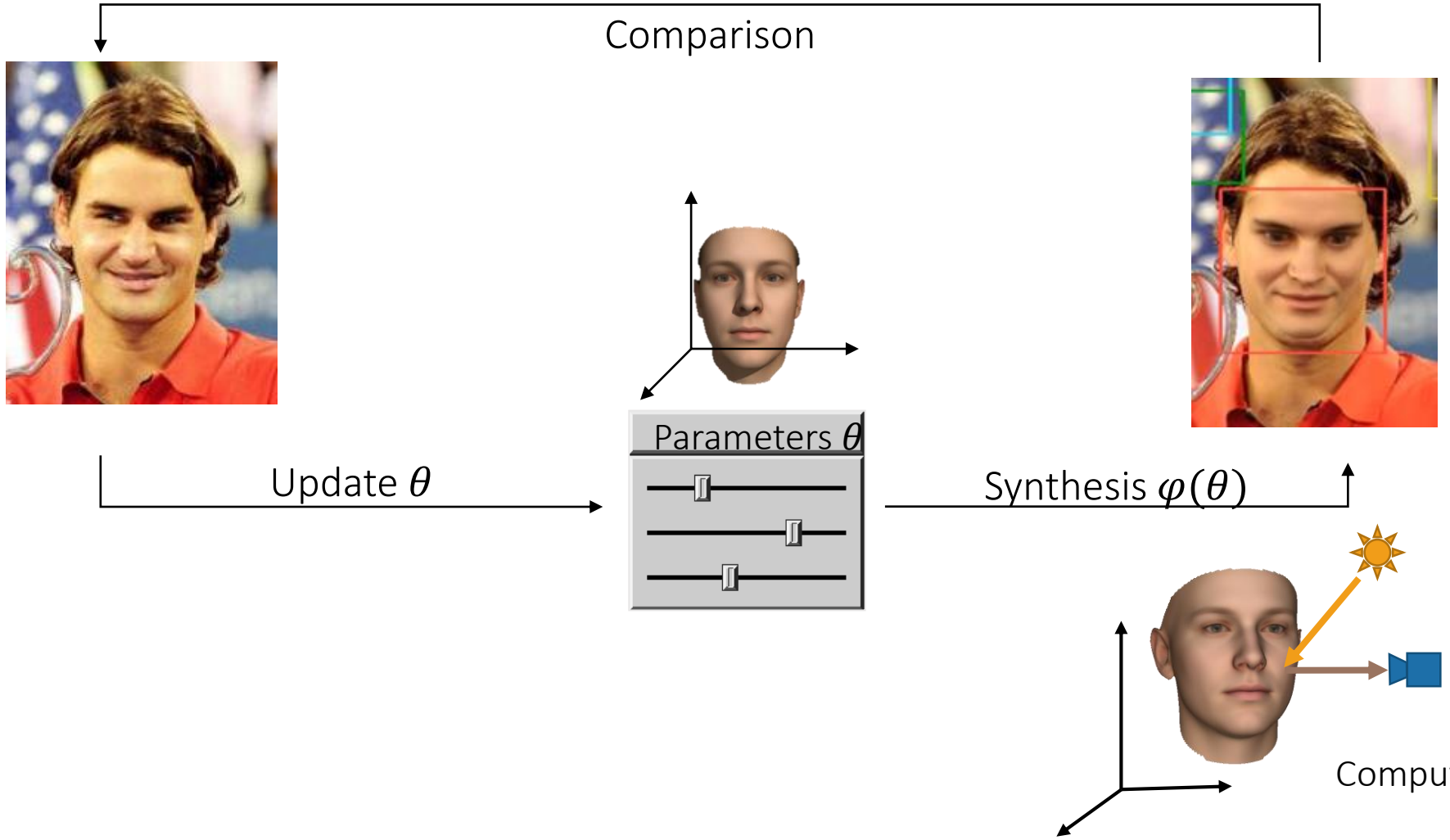
Scalismo

# Conceptual Basis: Analysis by synthesis

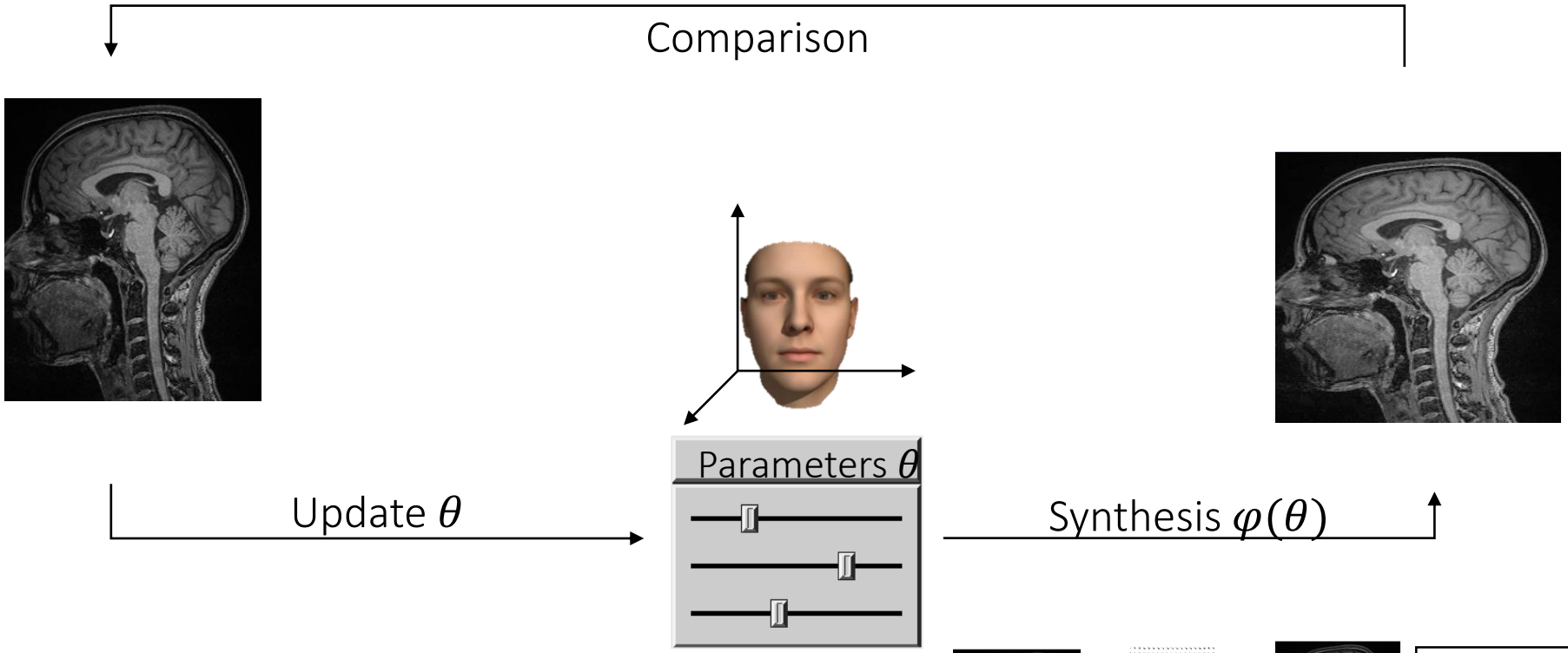



- If we are able to synthesize an image, we can explain it.
  - We can explain unseen parts and reason about them

# Synthesizing images

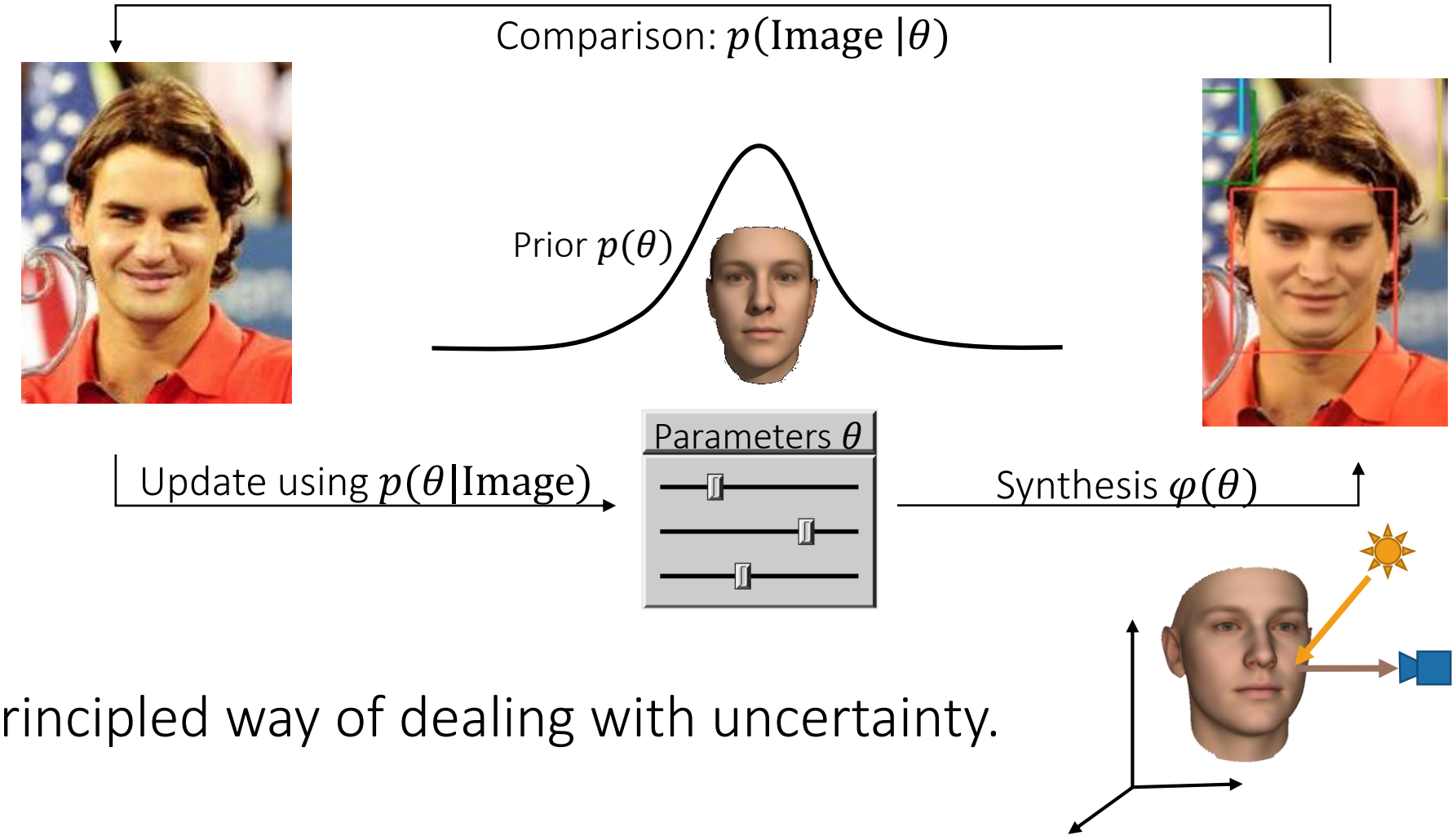


# Synthesizing images



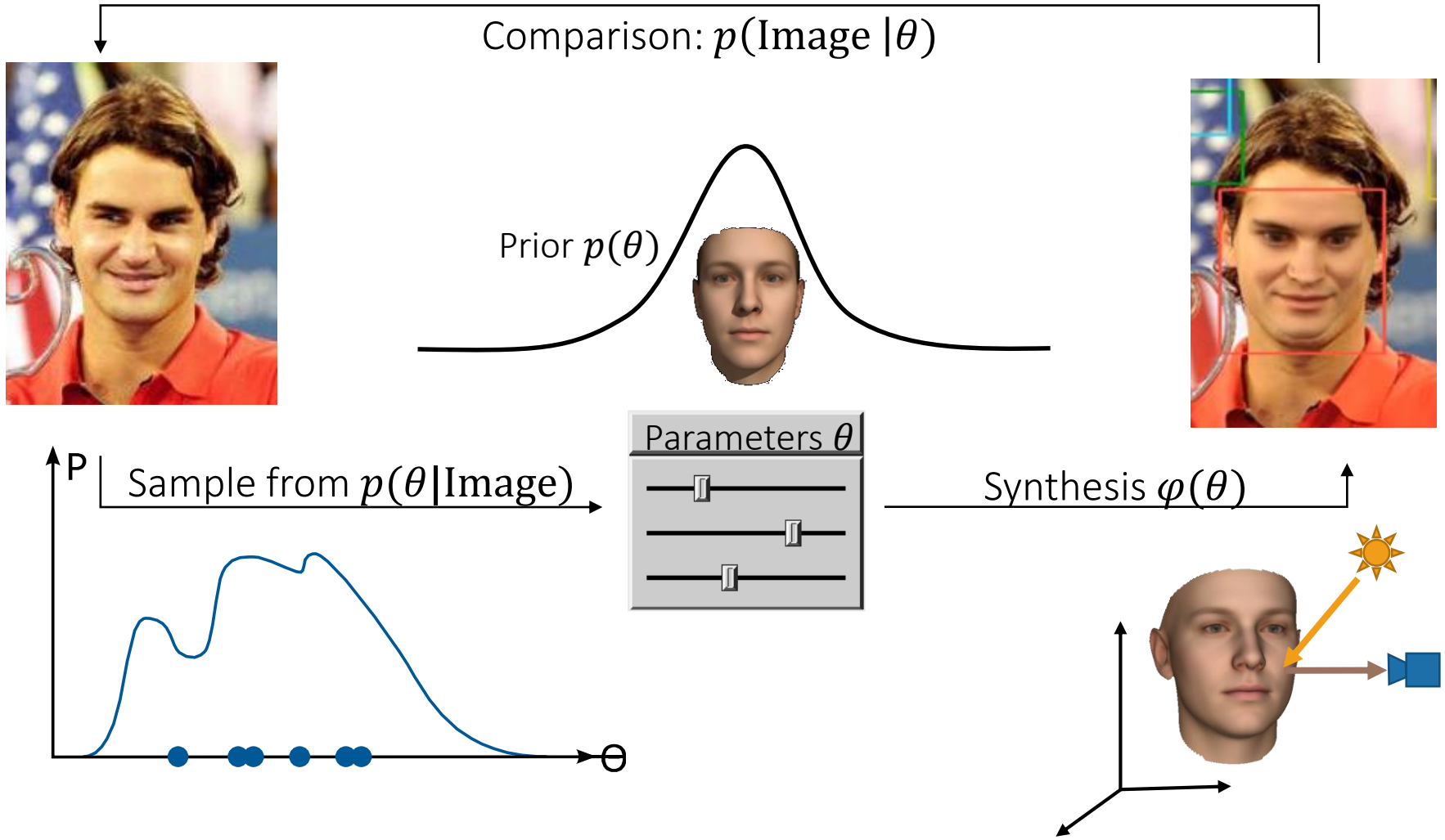

- Warping atlas images
- Simulating DRRs
- Virtual CTs

# Mathematical Framework: Bayesian inference




- Principled way of dealing with uncertainty.

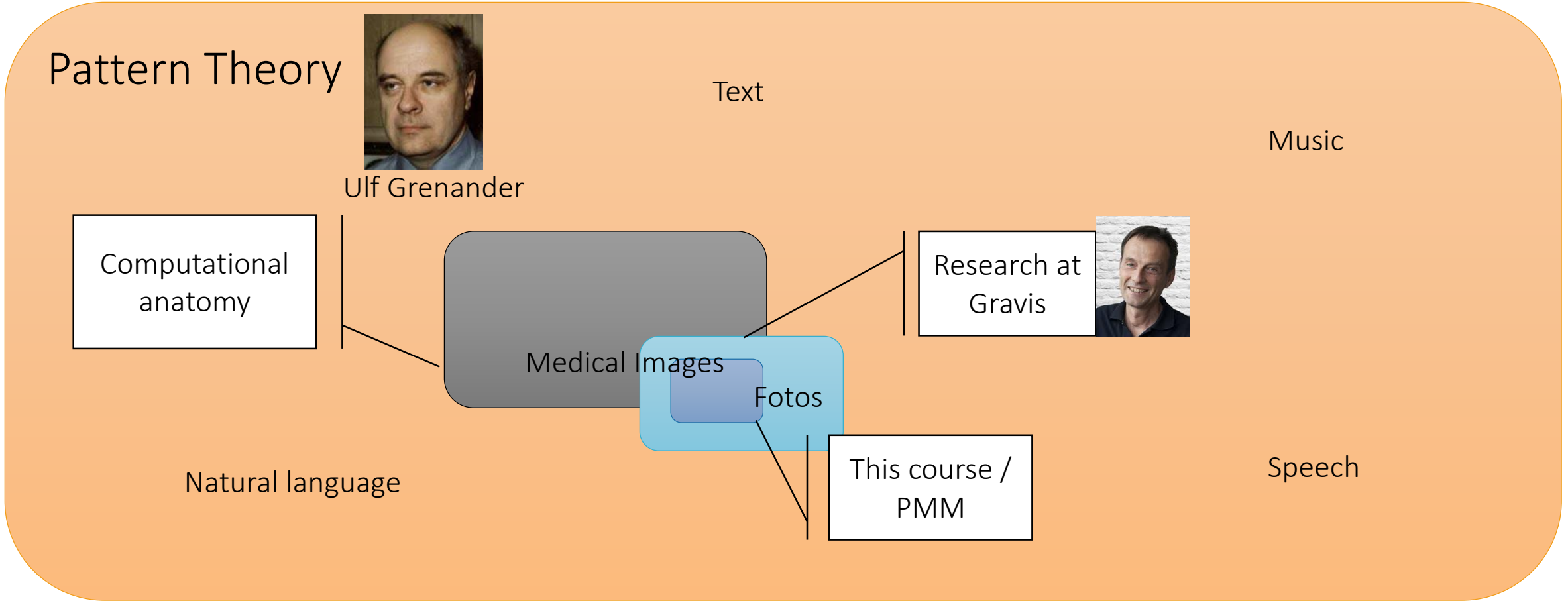
# Algorithmic implementation: MCMC



# Course programme

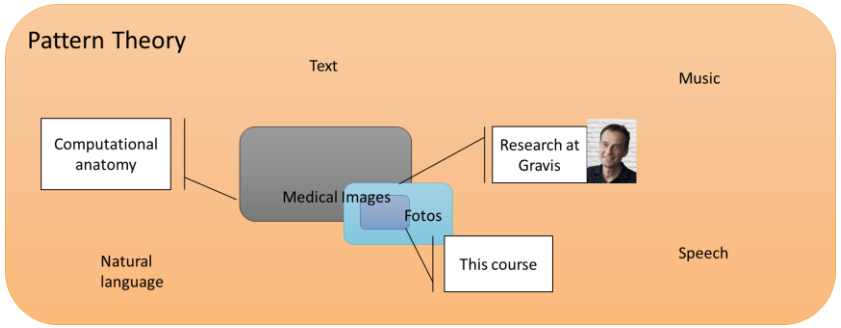
| | Morning | Afternoon |
|---|---|---|
| Tuesday | • Introduction<br>• The course at a glance<br>• Basics of Computer Graphics | • Basic tasks in Scalismo-faces<br>• Bayesian modelling<br>• Welcome reception |
| Wednesday | • Probabilistic model fitting using MCMC | • Exercises: MCMC Fitting<br>• Introduction to course project |
| Thursday | • Face image analysis | • Course project |
| Friday | • Connections to medical image analysis<br>• Advanced topics in Gaussian processes | • Course project |
| Saturday | • Project presentation | • Social event |

# The course in context

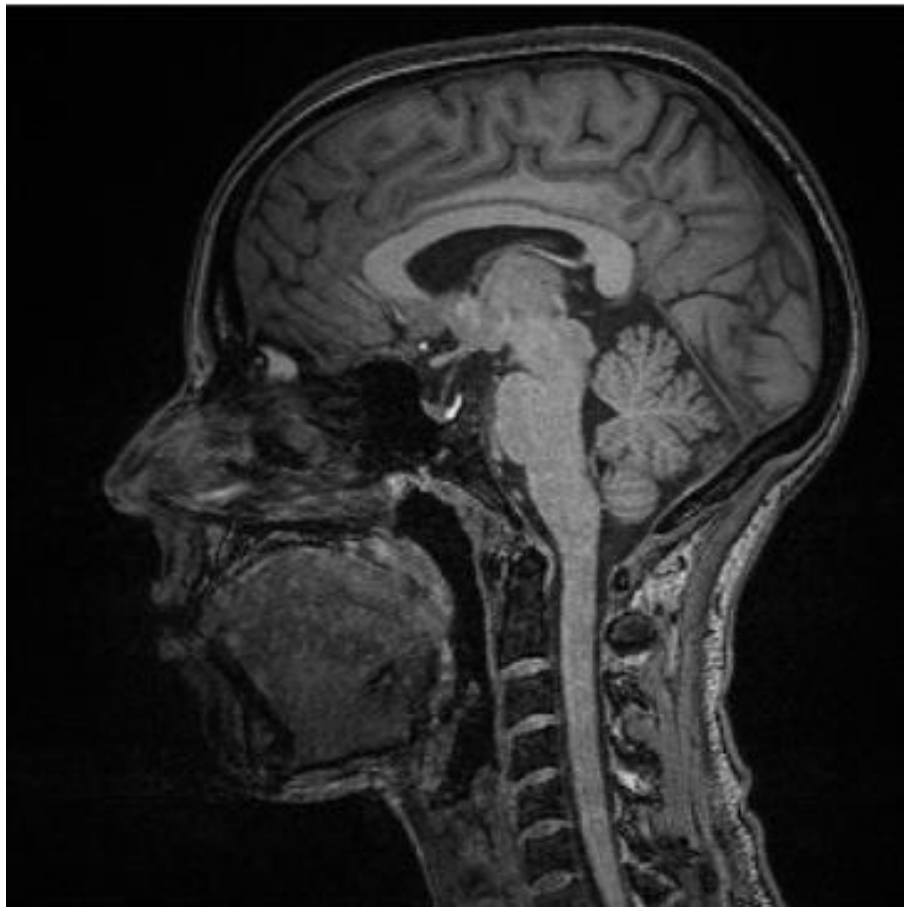


# Pattern theory vs PMM

- Pattern theory is about developing a theory for understanding real-world signals
- Probabilistic Morphable Models are about using theoretical well founded concepts to analyse images.
  - GPs for modelling
  - MCMC for model fitting
  - Working software



# Images: Medical Image Analysis vs Computer Vision



Source: OneYoungWorld.com

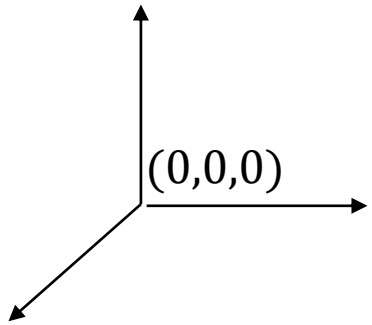
# Images in medical image analysis

Goal: Measure and visualize the unseen

- Acquired with specific purpose
  - Controlled measurement
  - Done by experts
- Calibrated, specialized devices

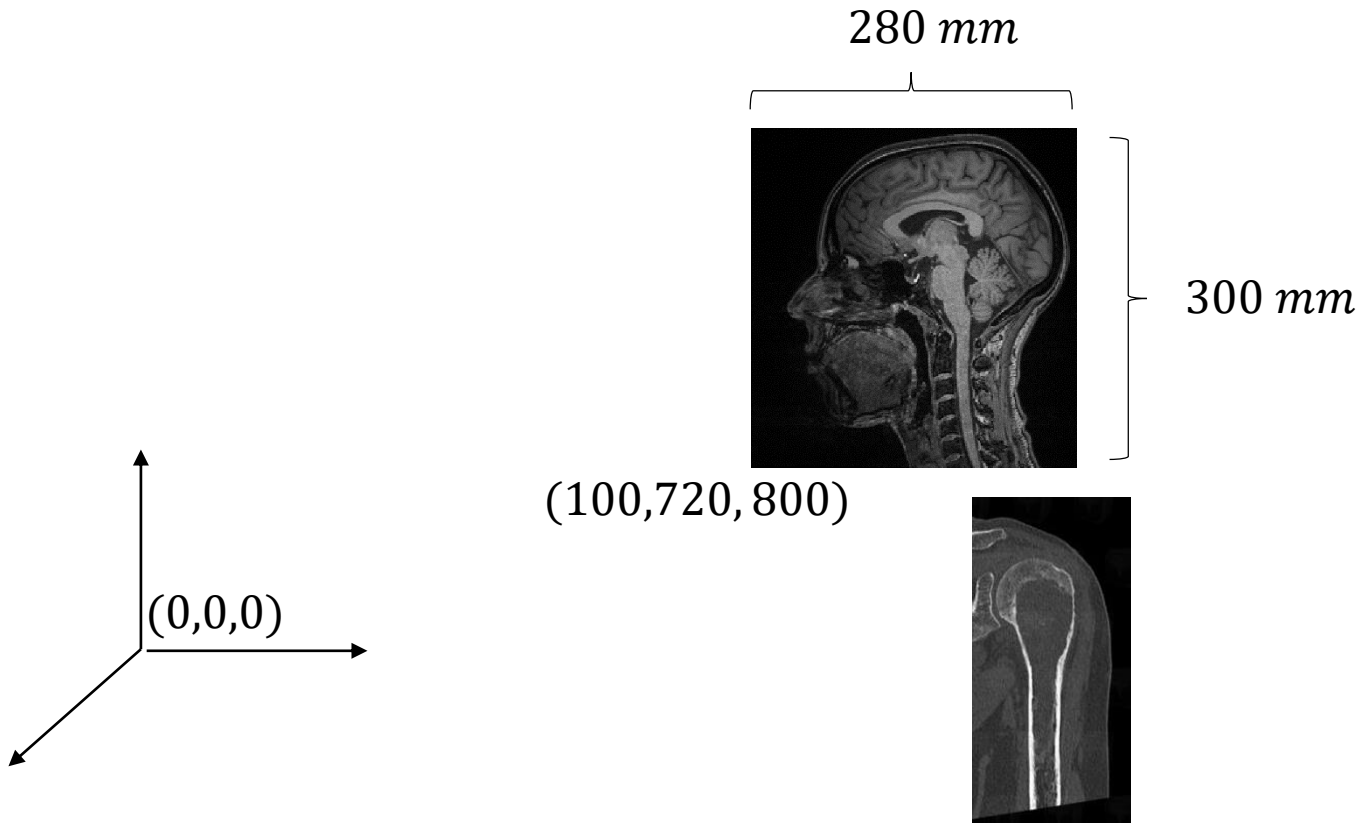

Source: www.siemens.com

# Images in medical image analysis




- Images live in a coordinate system (units: mm)

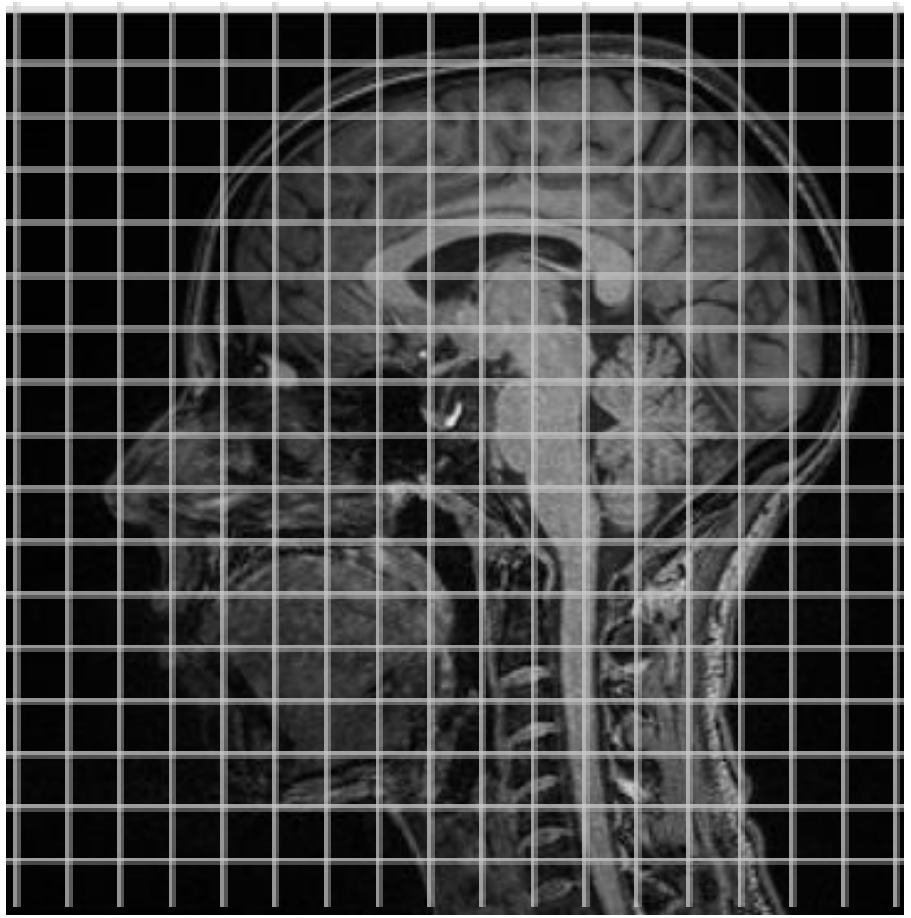
# Images in medical image analysis



# Images in medical image analysis

Values measure properties of the patient's tissue

- Usually scalar-valued
- Often calibrated
- CT Example:
  -1000 HU -> Air
  3000 HU -> cortical bone



# Images in computer vision

Goal: Capture what we see in a realistic way

- Perspective projection from 3D object to 2D image
  - Many parts are occluded

# Images in computer vision

- Can be done by anybody
  - Acquisition device usually unknown
  - Uncontrolled background, lighting, …
- No clear scale
  - What is the camera distance?
- No natural coordinate system
  - Unit usually pixel


Source: twitter.com

# Images in computer vision

- Pixels represent RGB values
- Values are measurement of light
  - Reproduce what the human eye would see
- Exact RGB value depends strongly on lighting conditions
  - Shadows
  - Ambient vs diffuse light

# Images: Medical Image analysis vs Computer Vision

**Medical image**

- Controlled measurement
- Values have (often) clear interpretation
- Explicit setup to visualize unseen
- Coordinate system with clear scale

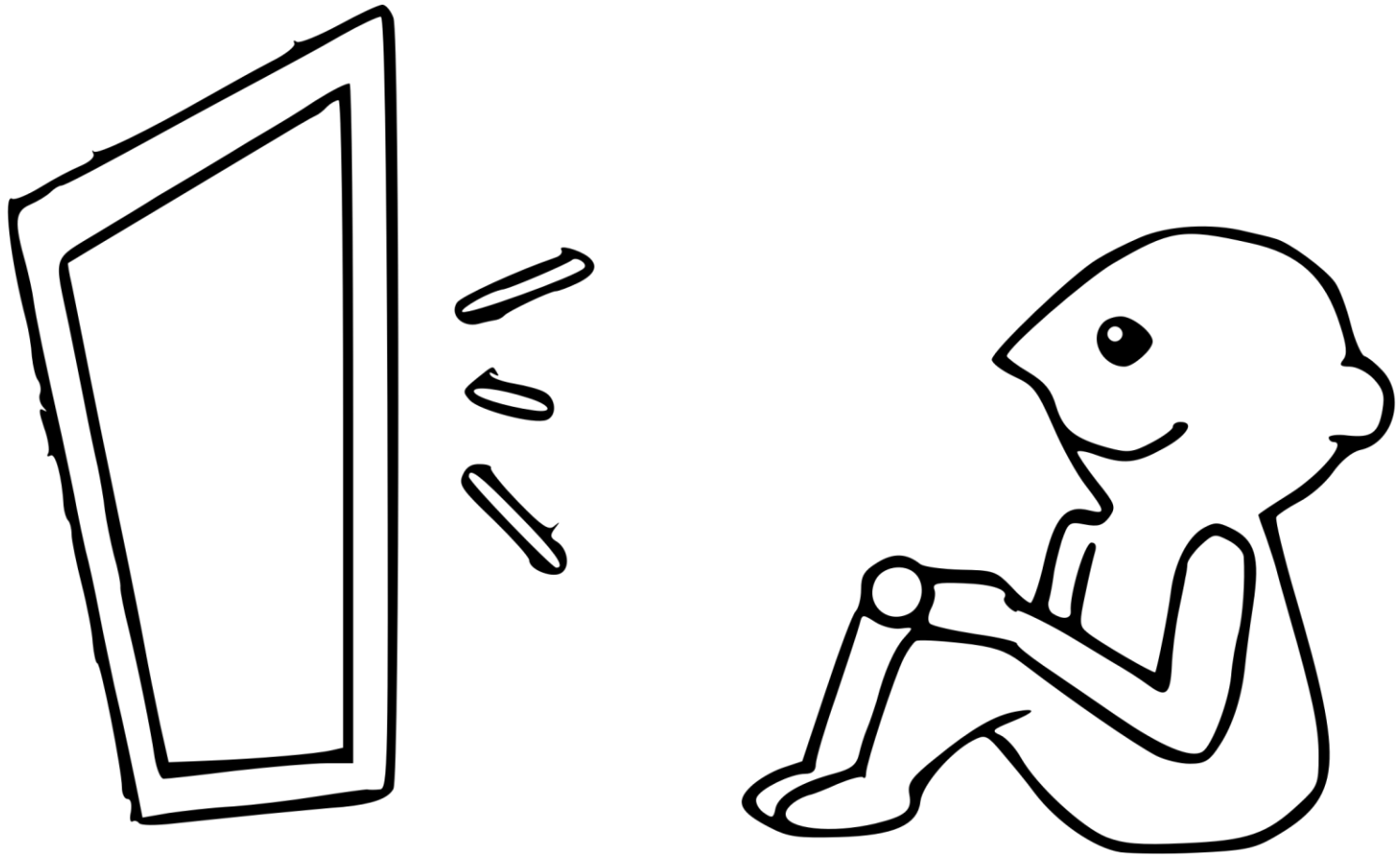
**Computer vision**

- Uncontrolled snapshot
- Values are mixture of different (unknown factors)
- Many occlusion due to perspective
- Scale unknown

Many complications of computer vision arise in different form also in a medical setting.

# The space of images

# The space of images



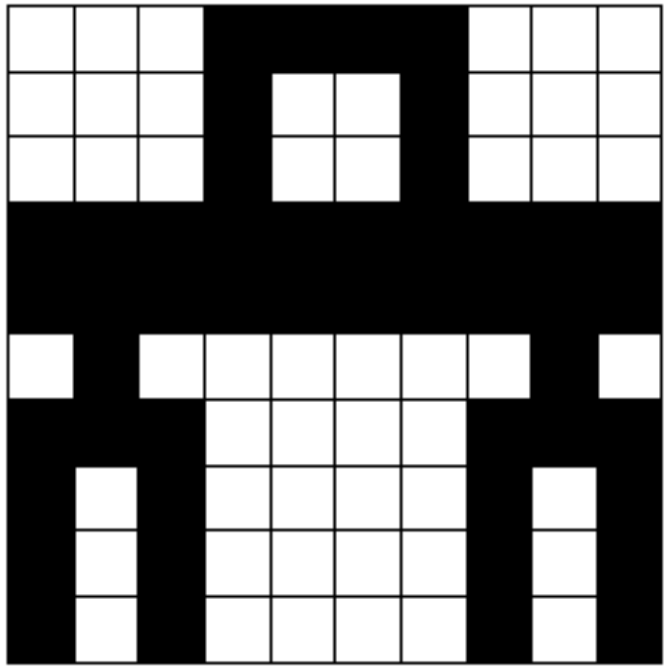
# The space of images

- 10 x 10 image
- 2 colours

How long would you need to watch TV (24 fps) until you have seen all such images?

- Number of images: $2^{100} \approx$ 1.2e30
- Watching 100 years continuously

  24 x 60 x 60 x 24 x 365 x 100 ≈7.5e10



Source: bbc.co.uk

# The space of images

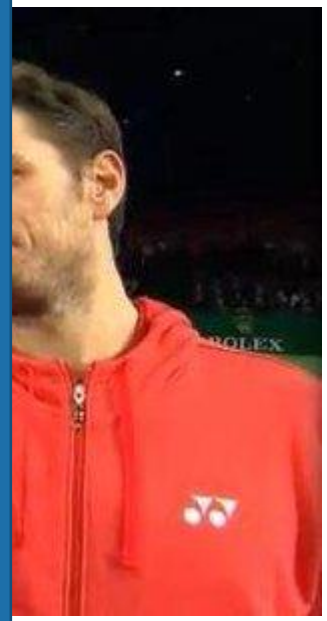
- Most images are uninteresting
- Only very few of all possible images are of interest to us

# Structure in images

- Image
- Image
  world
    - Str
      pro

Our mission:

- Model this structure
  - Needs only few parameters
- Explain image by finding appropriate parameters that reflect objects / laws / processes



# Next stop: Computer graphics