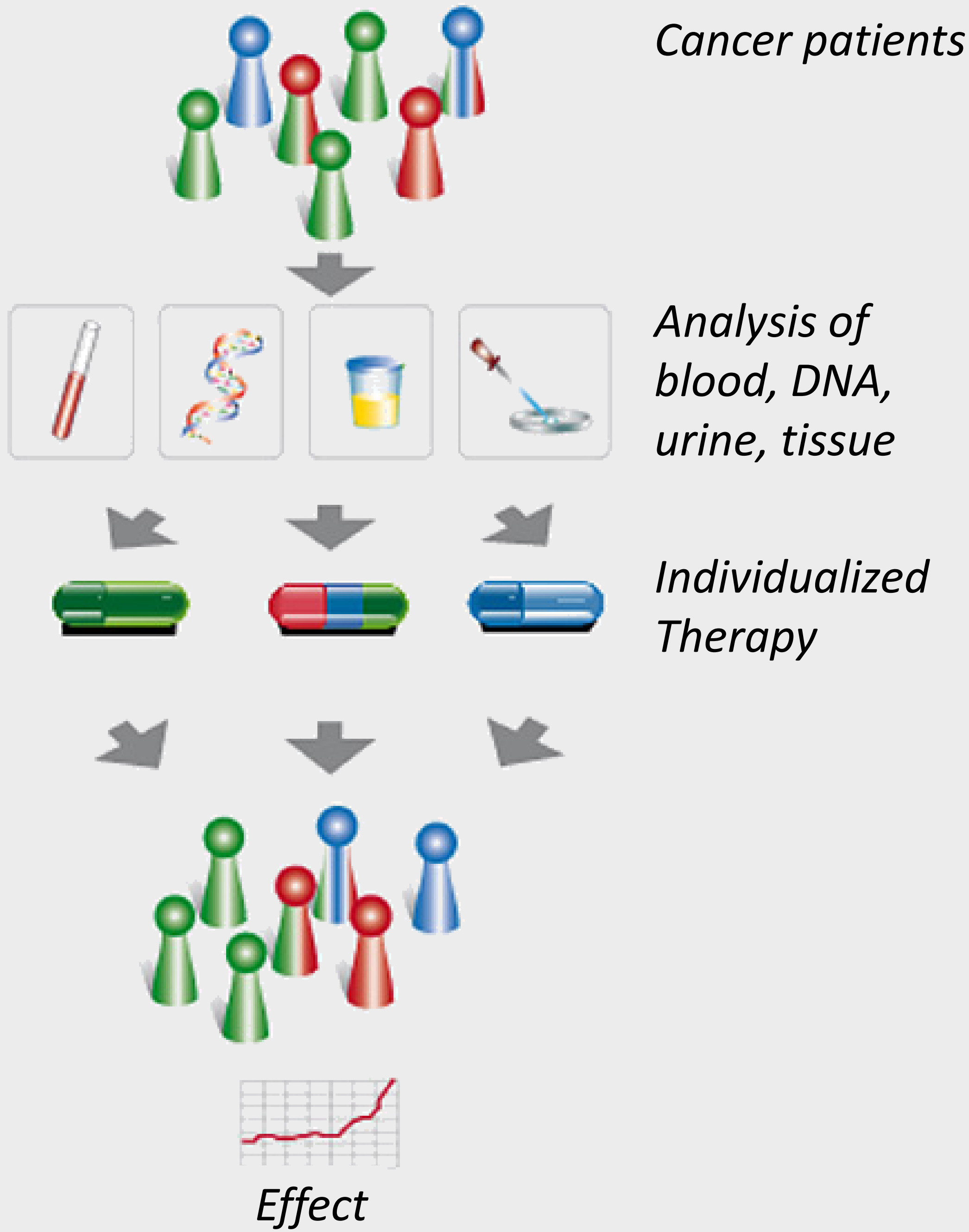
Radiomics

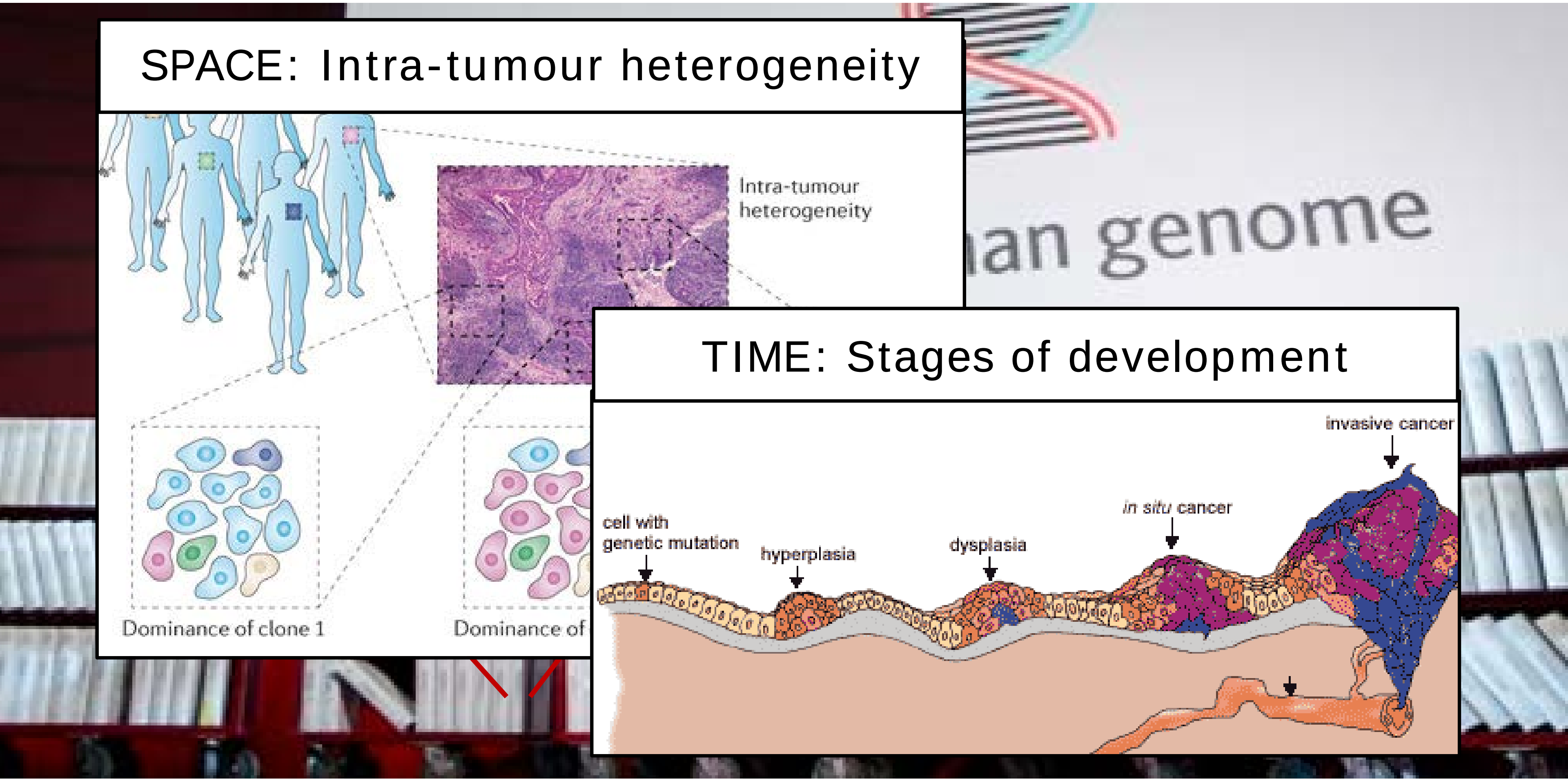
PD Dr. rer. nat. Klaus H. Maier-Hein (né Fritzsche)
Head of junior research group Medical Image Computing

GERMAN
CANCER RESEARCH CENTER
IN THE HELMHOLTZ ASSOCIATION

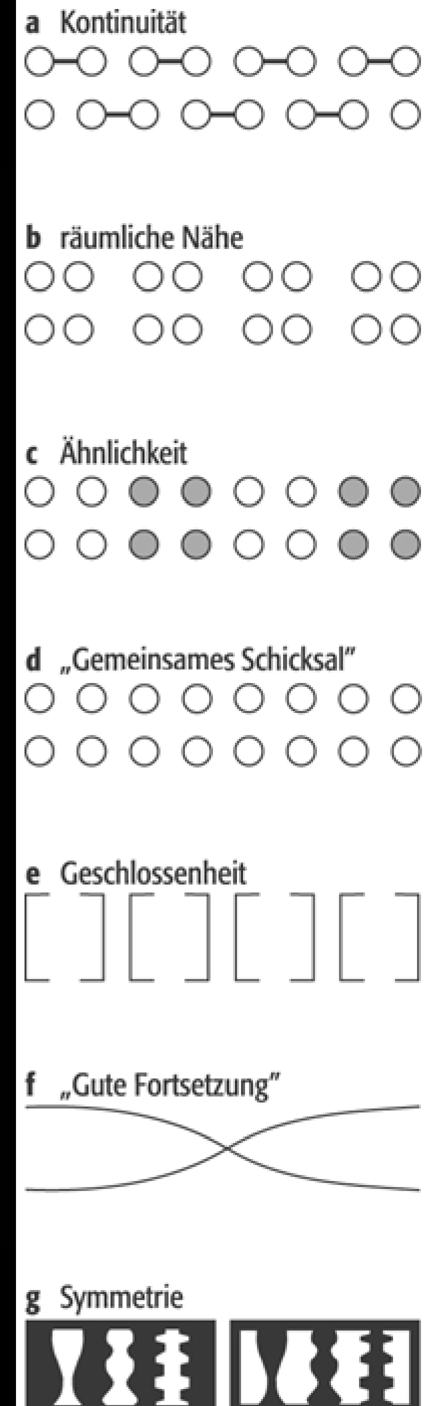
50 Years – Research for
A Life Without Cancer


Cancer patients
Analysis of blood, DNA, urine, tissue
Individualized Therapy
Effect

Big data challenge in precision oncology



RSNA 2014, www.siemens.com



From data to information

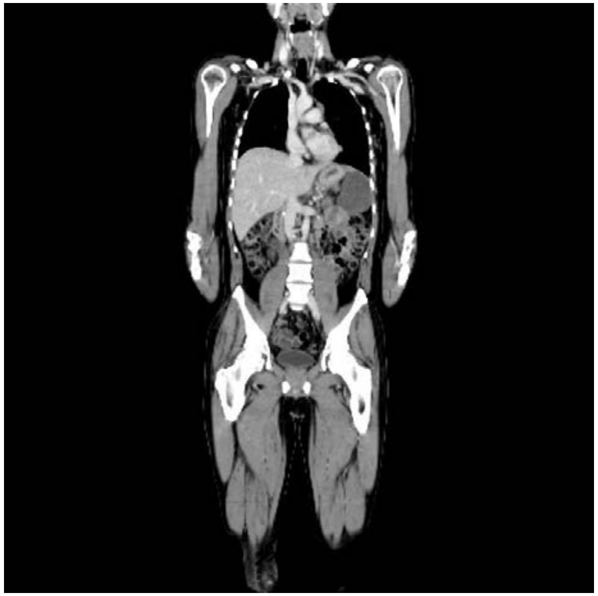


Image data

MRT Institut
am Friedrichshain

Dr. med., Dipl. Phys. B. Lehmann Facharzt für Radiologische Diagnostik

Landsberger Allee 49
10249 Berlin
Telefon (030) 420 143 80

Berlin - Friedrichshain, 01.03.02

Frau Dr. med.
Bettina Szulmistrat
Kienbergstr. 58

12685 Berlin

Kohl Stephan, geb. am 27.04.1967,

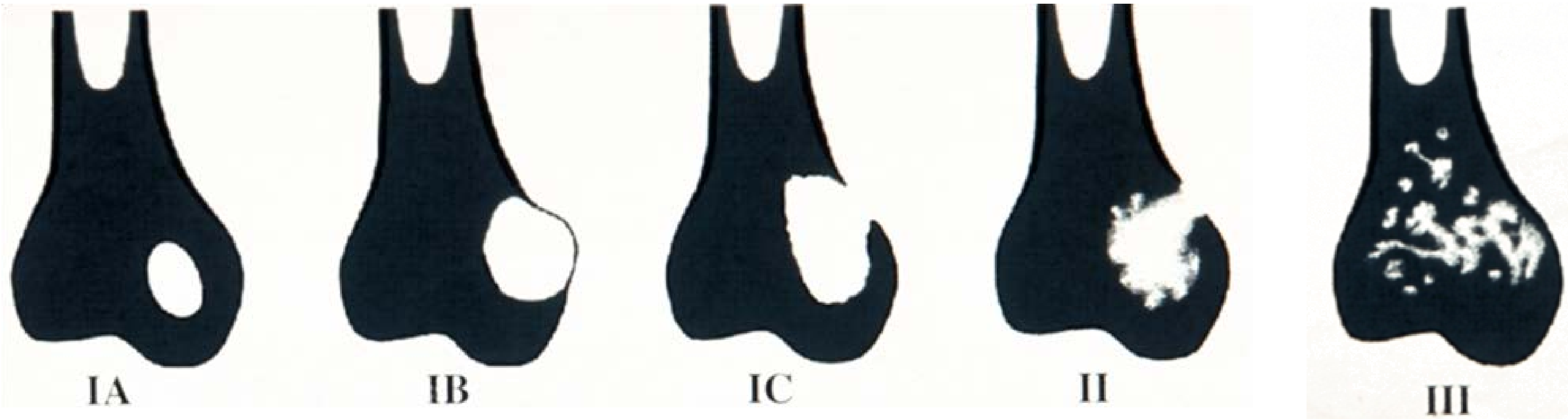
Sehr geehrte Kollegin,

vielen Dank für die Überweisung Ihres o.g. Patienten, der sich am 28.02.02 vorstellte. Es wurden folgende Untersuchungen durchgeführt:
MRT des Schädels nativ sowie nach Kontrastmittel

Befund:

Medical report

Quantitative radiology?



IA
- geographic
- thin, sclerotic margin

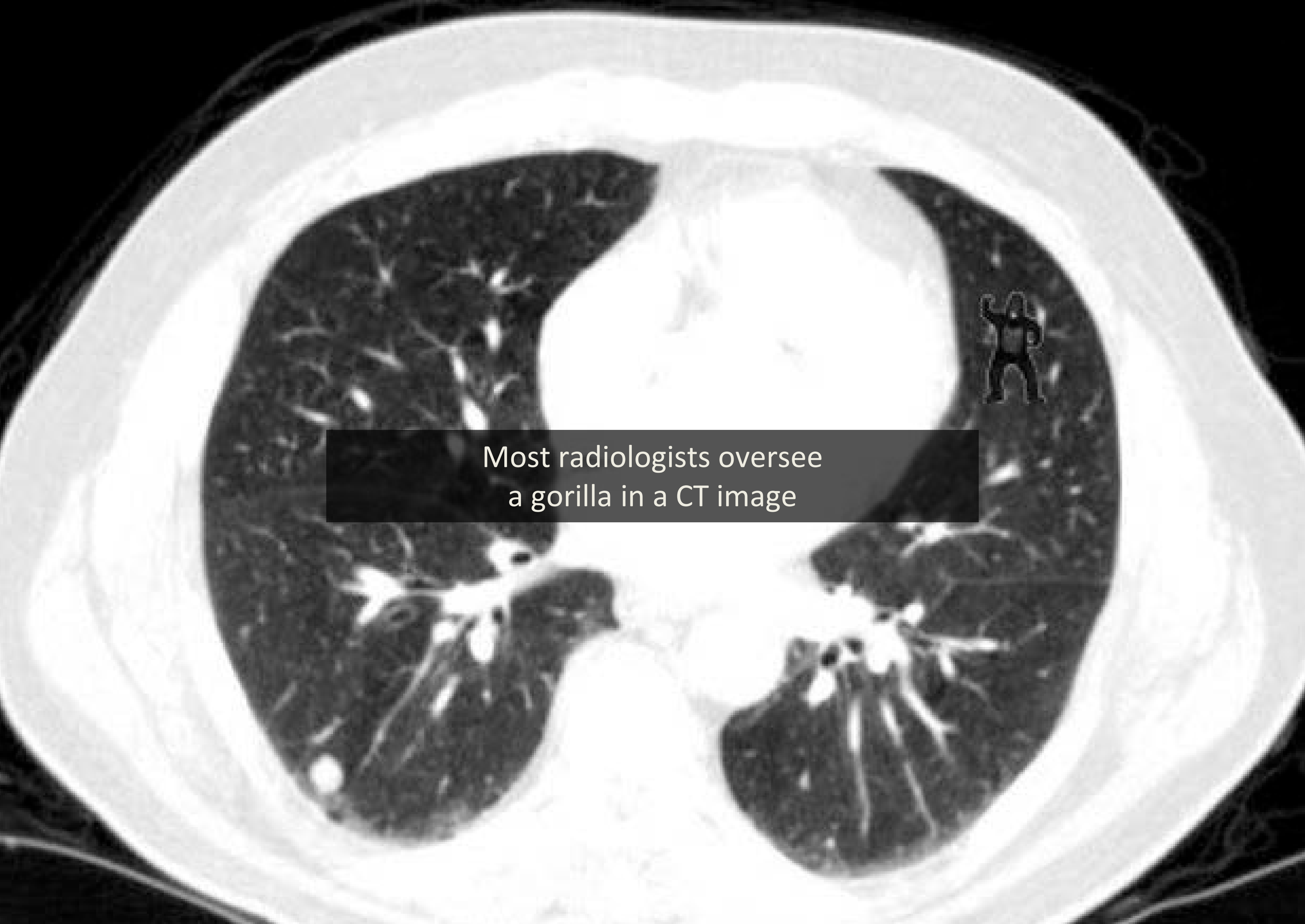
IB
- geographic
- distinct, well-marginated border
- not sclerotic

IC
- geographic
- indistinct border

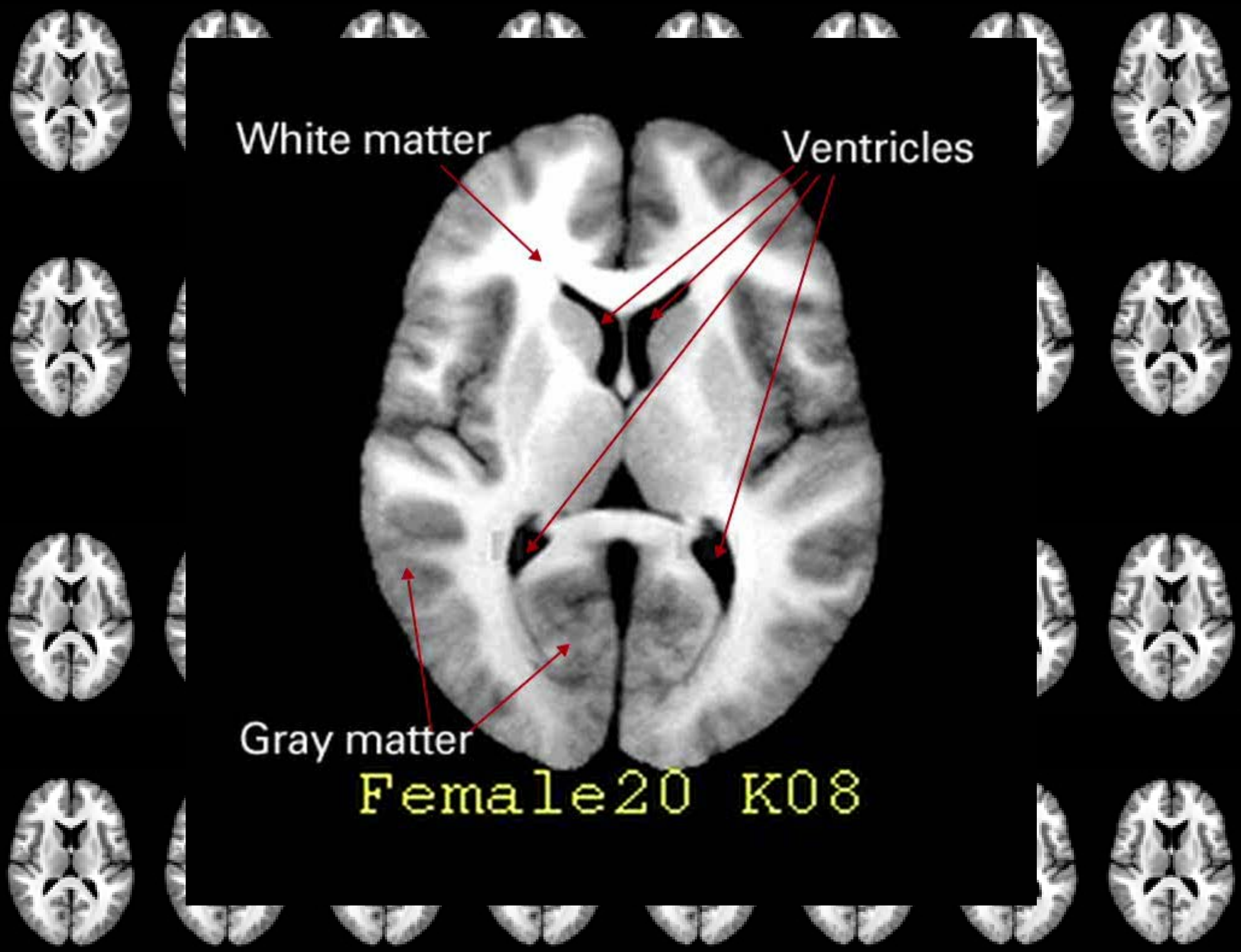
II
- moth-eaten

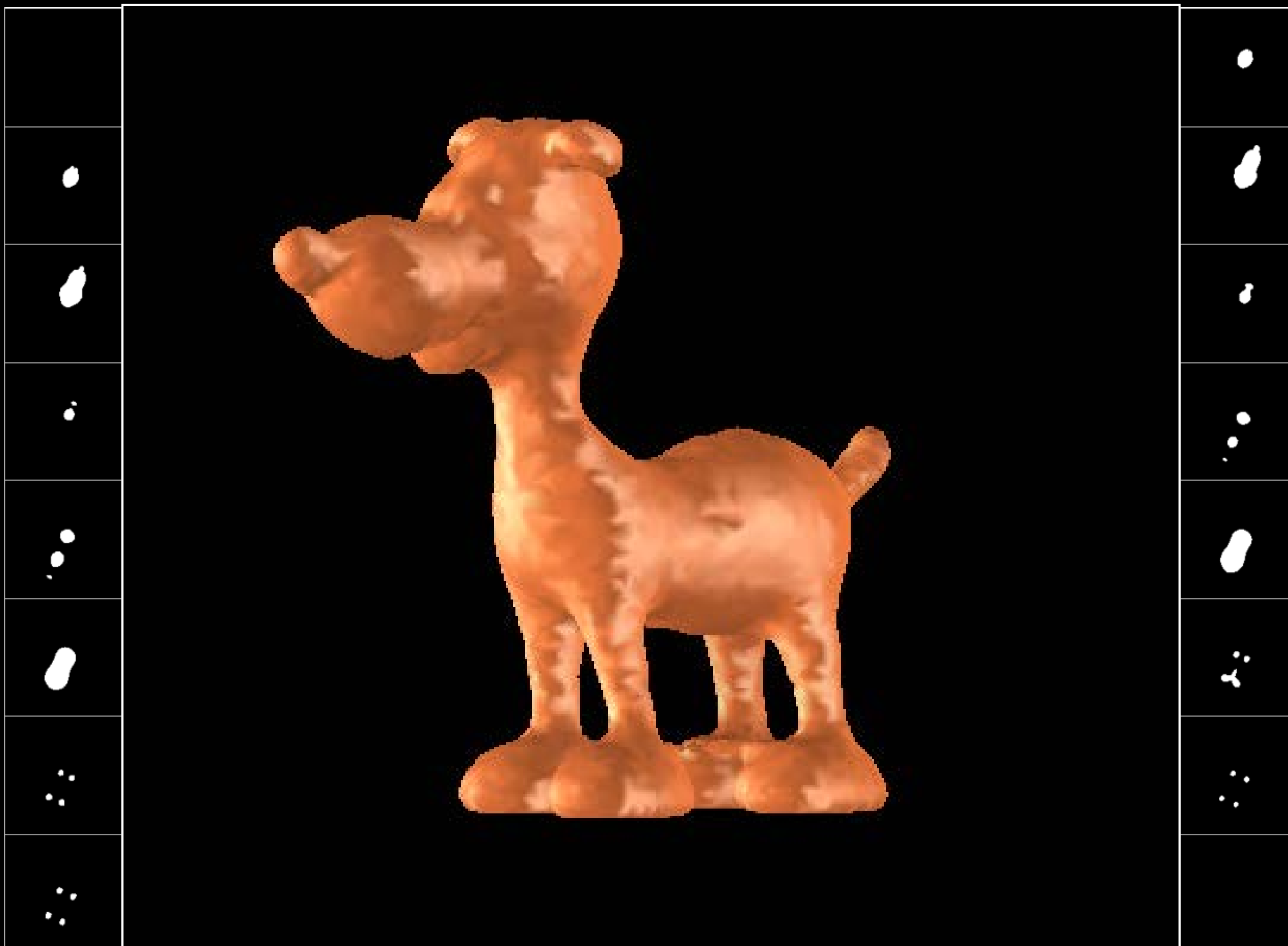
III
- permeative

Uhl und Herget. *Thieme Verlag* (2008)



Trafton *et al.* Psychol Sci (2013)


White matter
Ventricles
Gray matter
Female20 K08



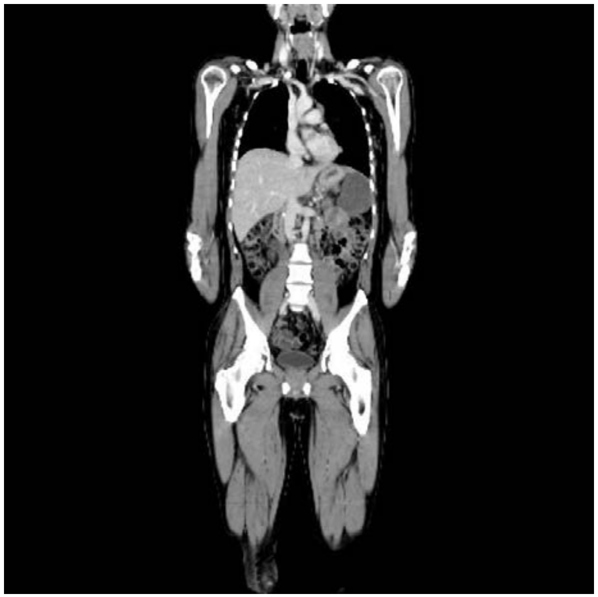
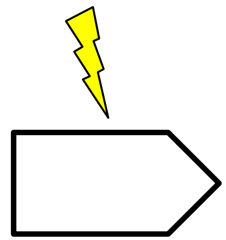
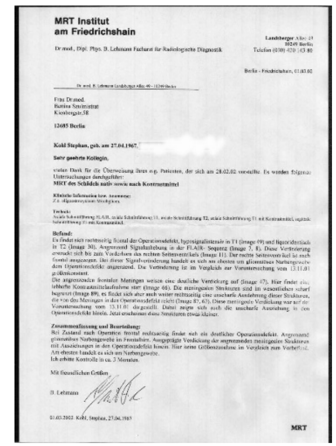


Image data
(many gigabytes)





MRT Institut
am Friedrichshain

MRT

Medical report
(few kilobytes)

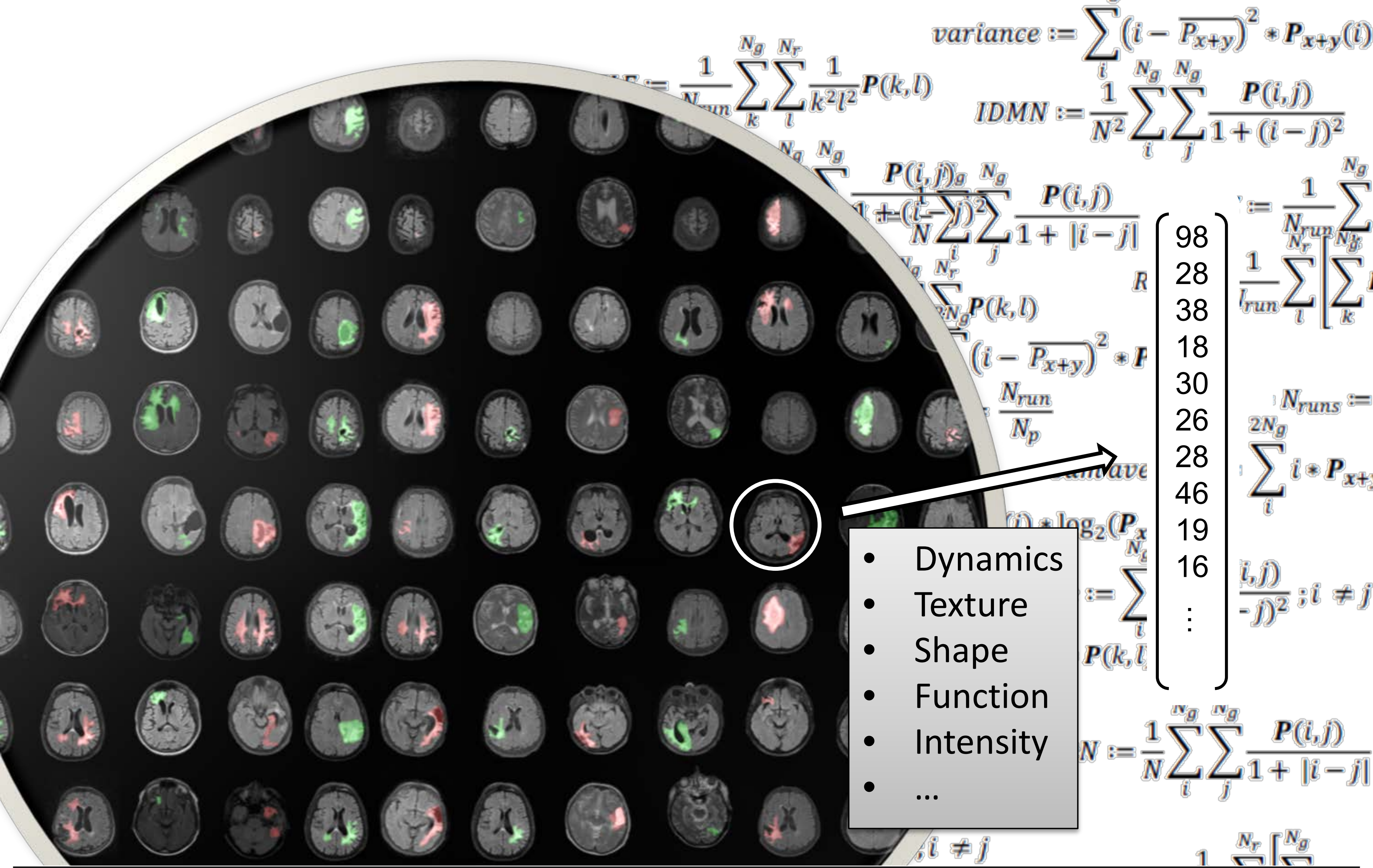
Outline

1. **Radiomics - Introduction**
2. Machine Learning
3. Computer Vision
4. Radiomics – Challenges ahead

„-omics“

a field of study studying
the totality of some sort

Radiomics: Sequencing of images



- Dynamics
- Texture
- Shape
- Function
- Intensity
- …

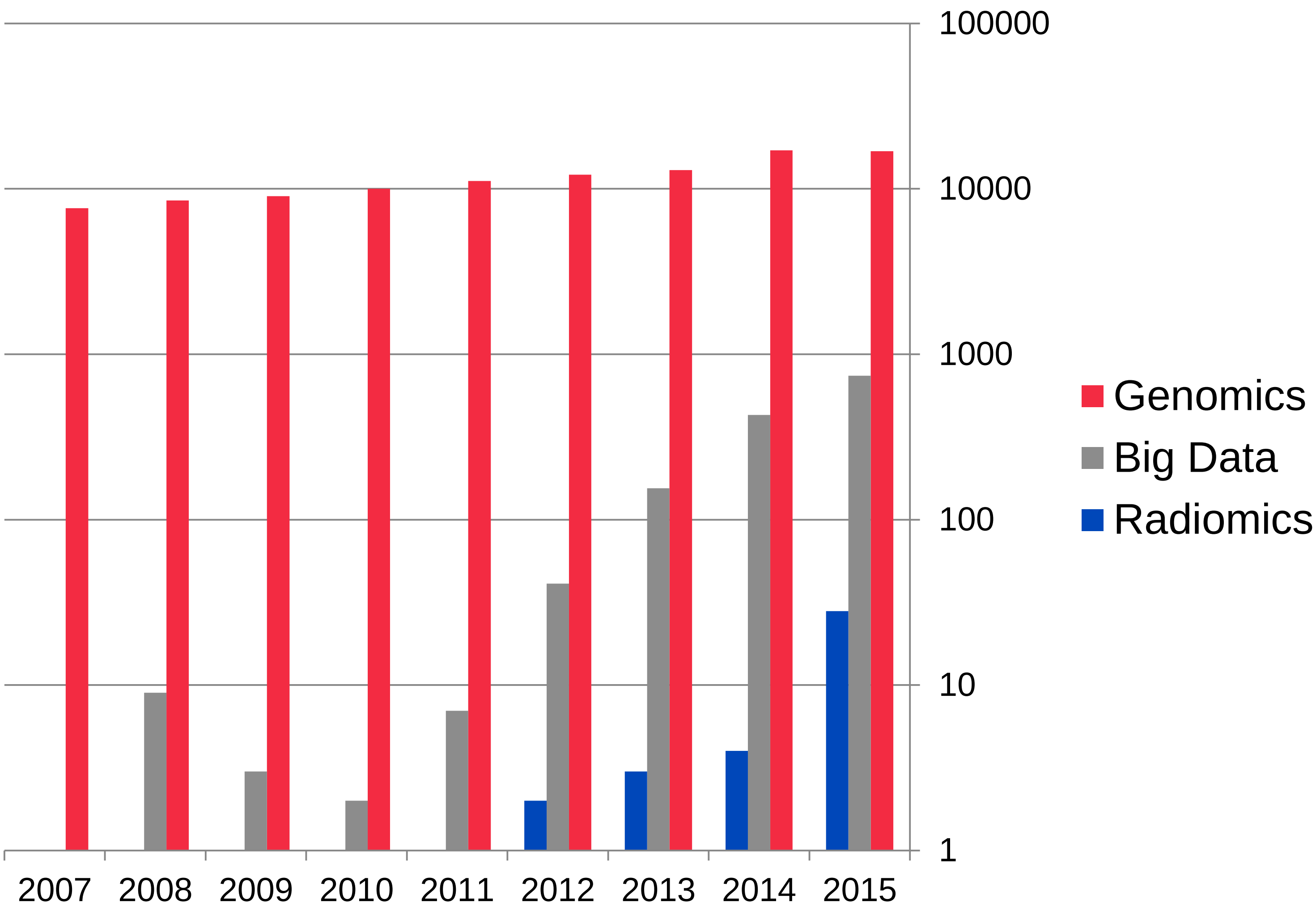
$$\begin{pmatrix} 98 \\ 28 \\ 38 \\ 18 \\ 30 \\ 26 \\ 28 \\ 46 \\ 19 \\ 16 \\ \vdots \end{pmatrix}$$

„Radiomics“

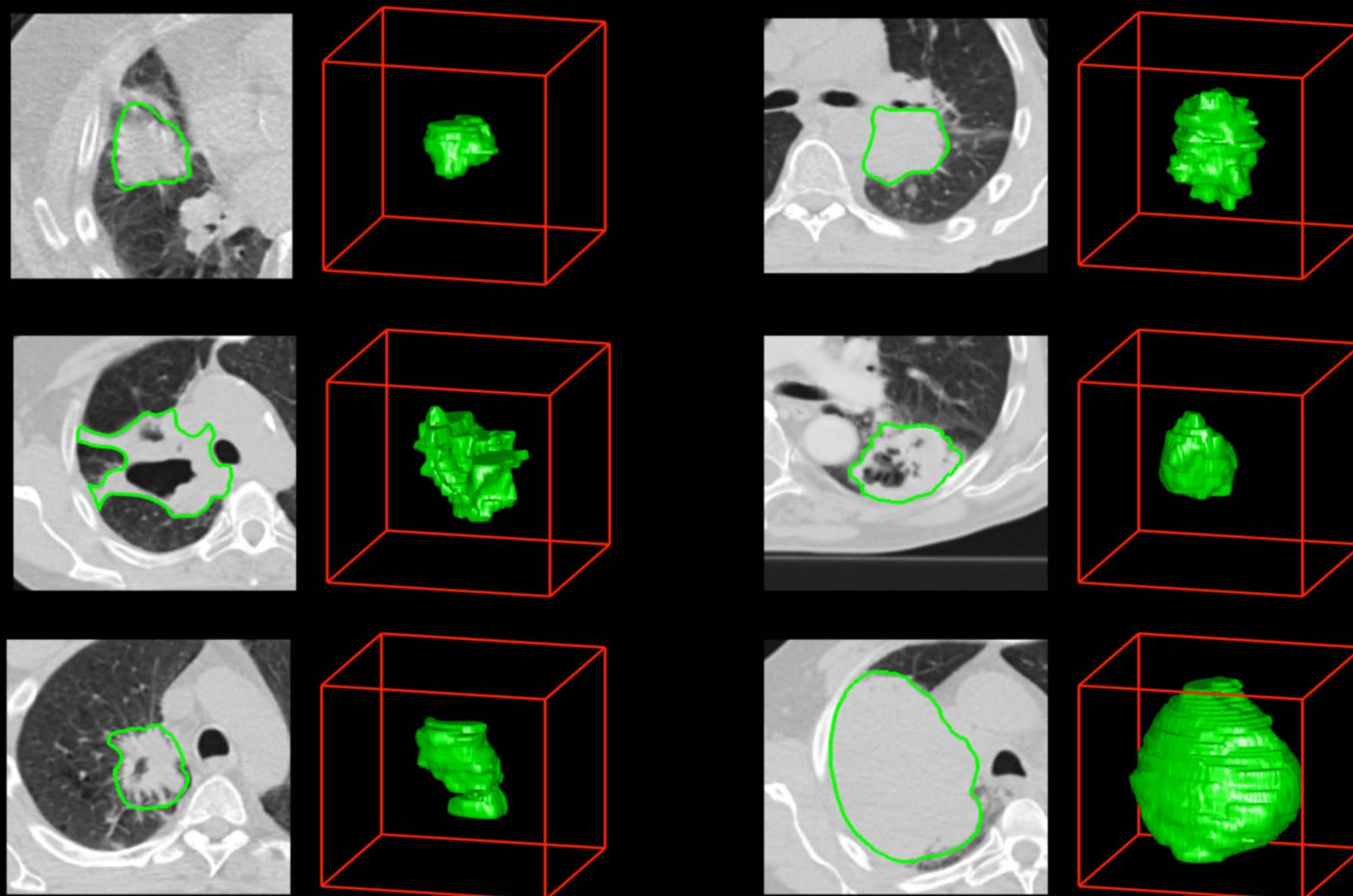
analyzing large amounts of
quantitative image features

Kumar *et al. Magn Reson Imag* (2012)

„Radiomics“ in Pubmed

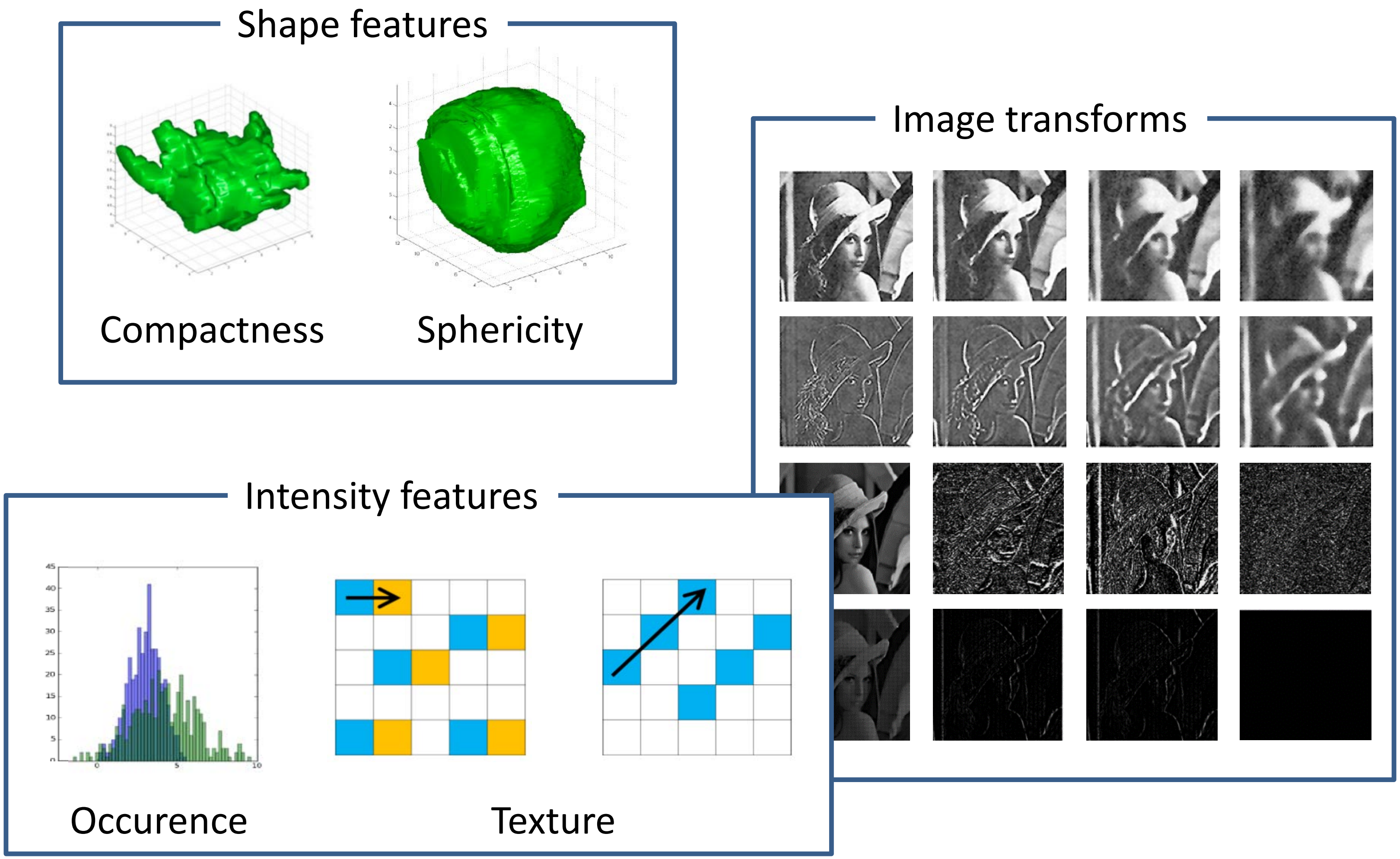


Tumors differ from each other

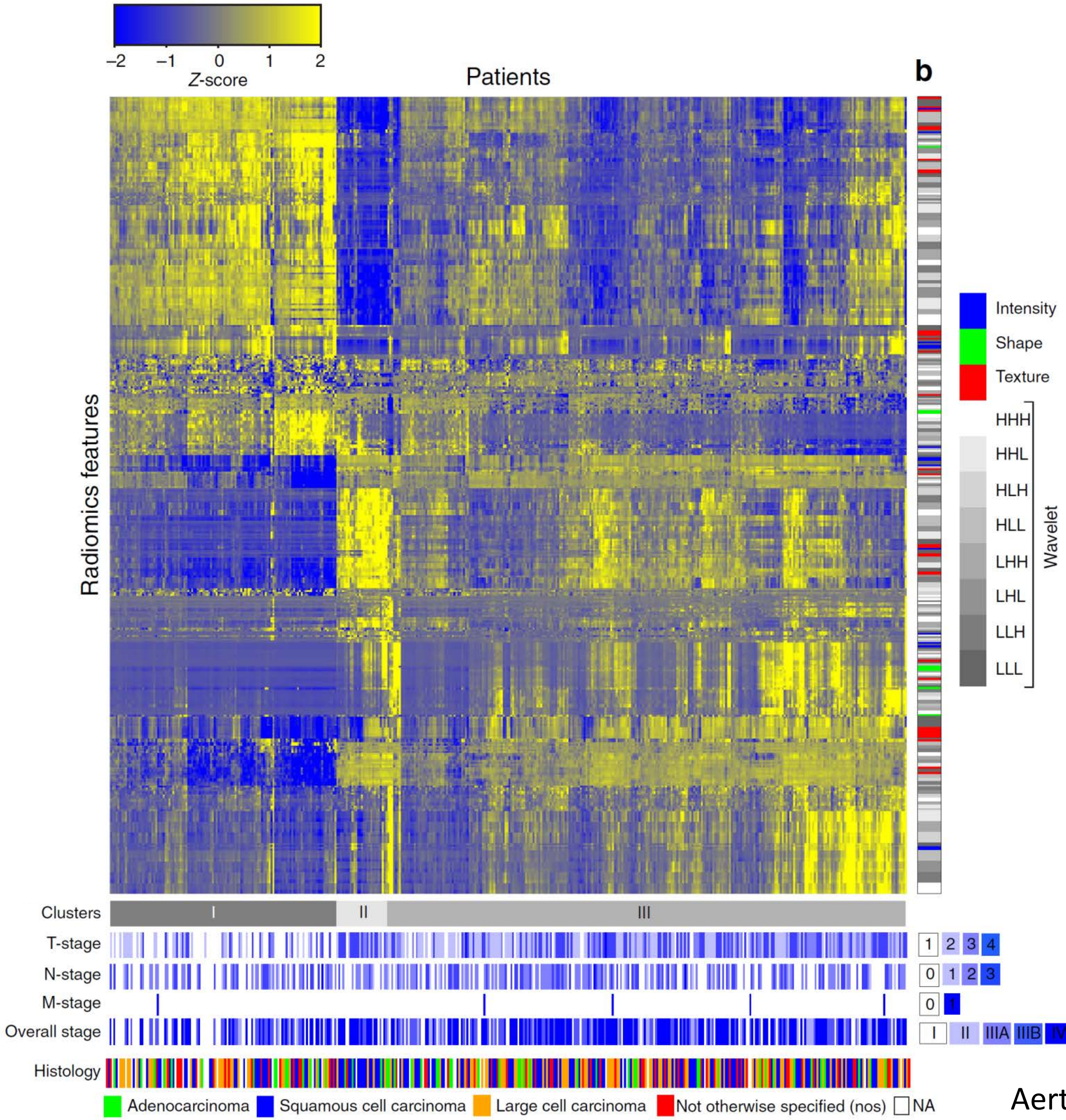


Aerts *et al.* (2014)

Quantitative features capture the phenotyp



Aerts *et al.* (2014)



Aerts *et al.* (2014)

Where do we go from here?

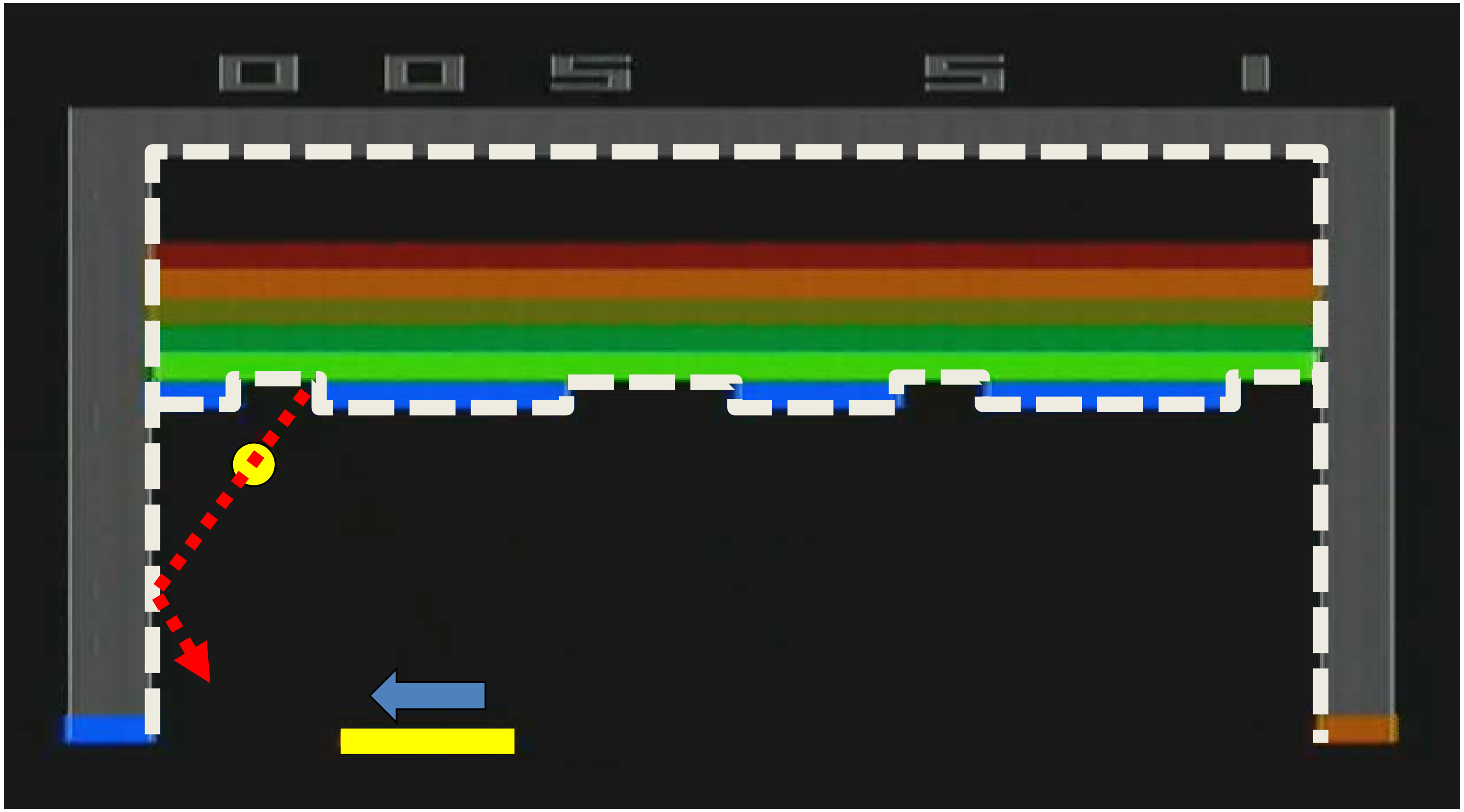
- Complete? Redundant?
- Transferable?
- Only CT?
- Only single lesions?
- IT-Infrastructur?
- Efficient? Reproducible?

Outline

1. Radiomics - Introduction
2. **Machine Learning**
3. Computer Vision
4. Radiomics – Challenges ahead

Atari 2600: „Breakout“

„Programed behavior“



After 100 Games

Mnih *et al.* *Nature* (2015)

Mnih *et al. Nature* (2015)

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1. Radiomics - Introduction
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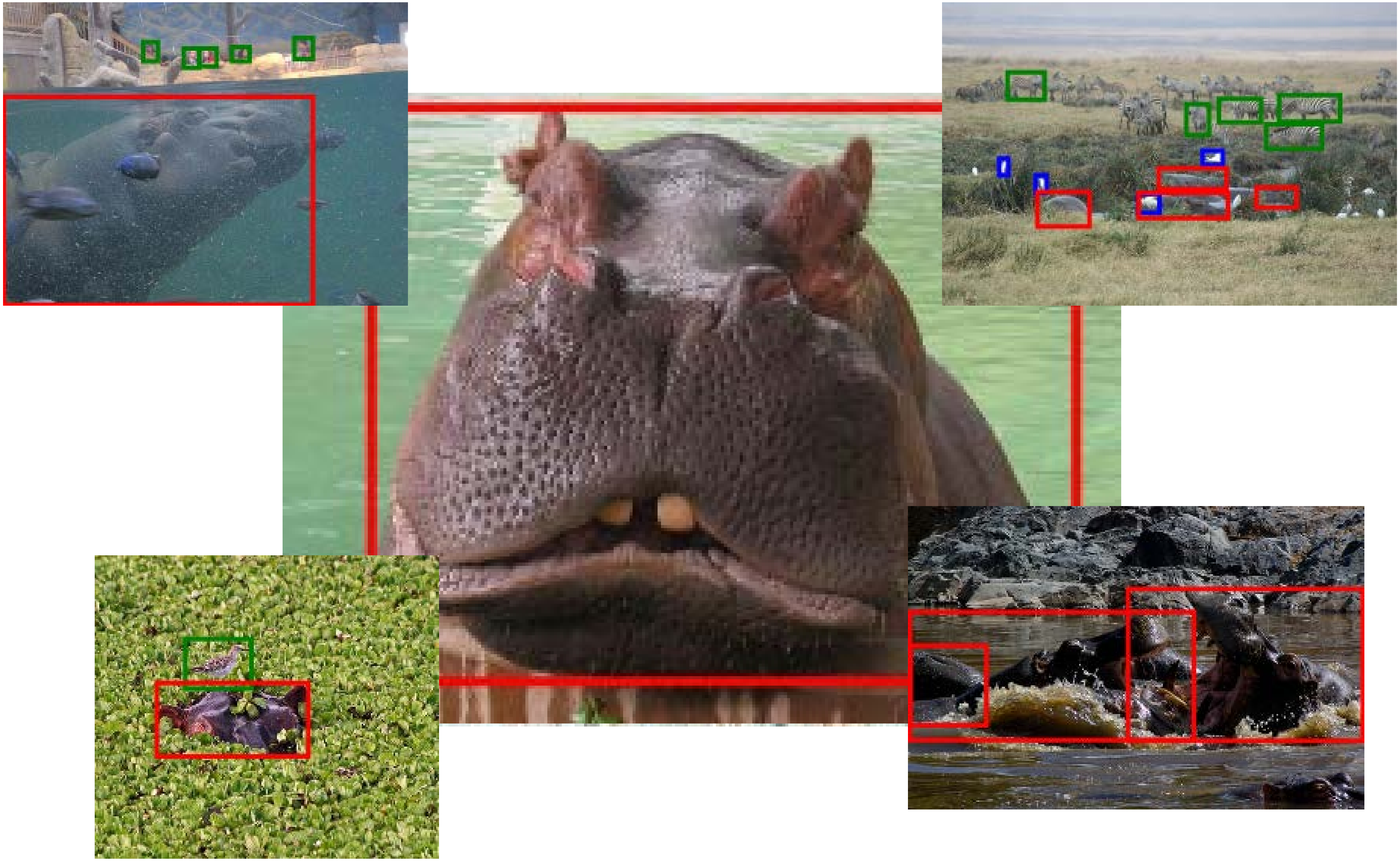
Detecting Objects in Images



www.image-net.org

2011: Computers outperform humans

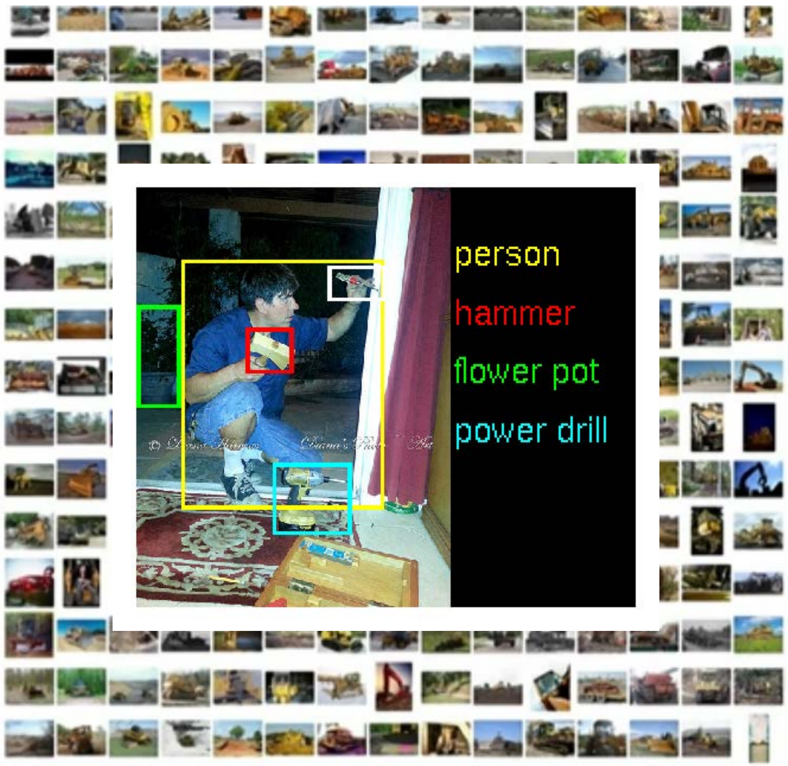
TEAM	METHOD	TOTAL
[3] IDSIA ⭐	Committee of CNNs	99.46%
[1] INI-RTCV ⭐	Human Performance	98.84%
[4] sermanet ⭐	Multi-Scale CNNs	98.31%
[2] CAOR ⭐	Random Forests	96.14%
[6] INI-RTCV	LDA on HOG 2	95.68%
[5] INI-RTCV	LDA on HOG 1	93.18%
[7] INI-RTCV	LDA on HOG 3	92.34%

- Single-image, multi-class classification problem
- More than 40 classes
- More than 50,000 images in total
- Large, lifelike database

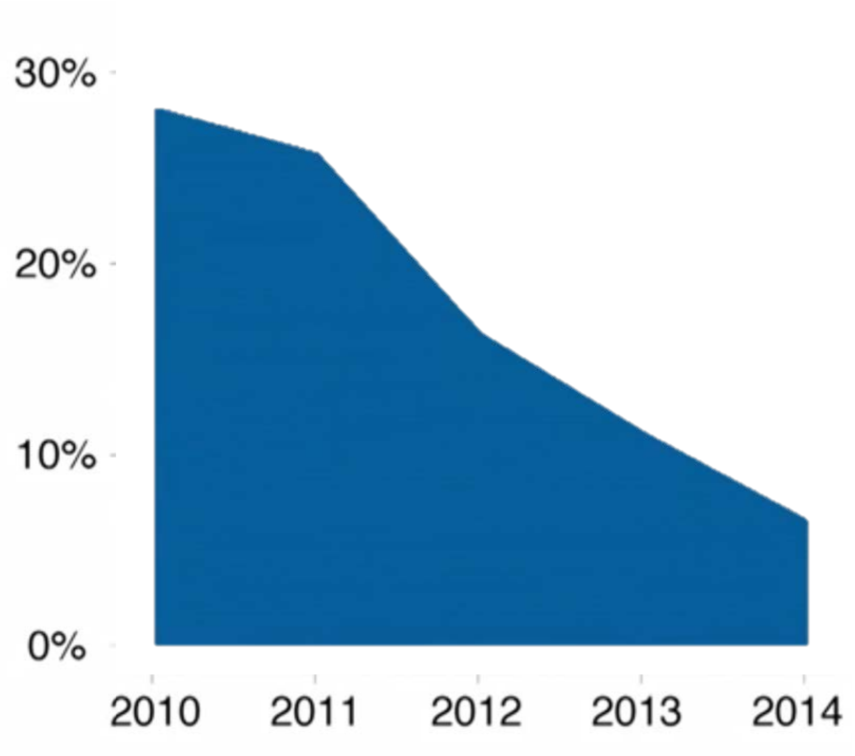
http://benchmark.ini.rub.de/

2014: ImageNet

ImageNet: 1.5 mio images

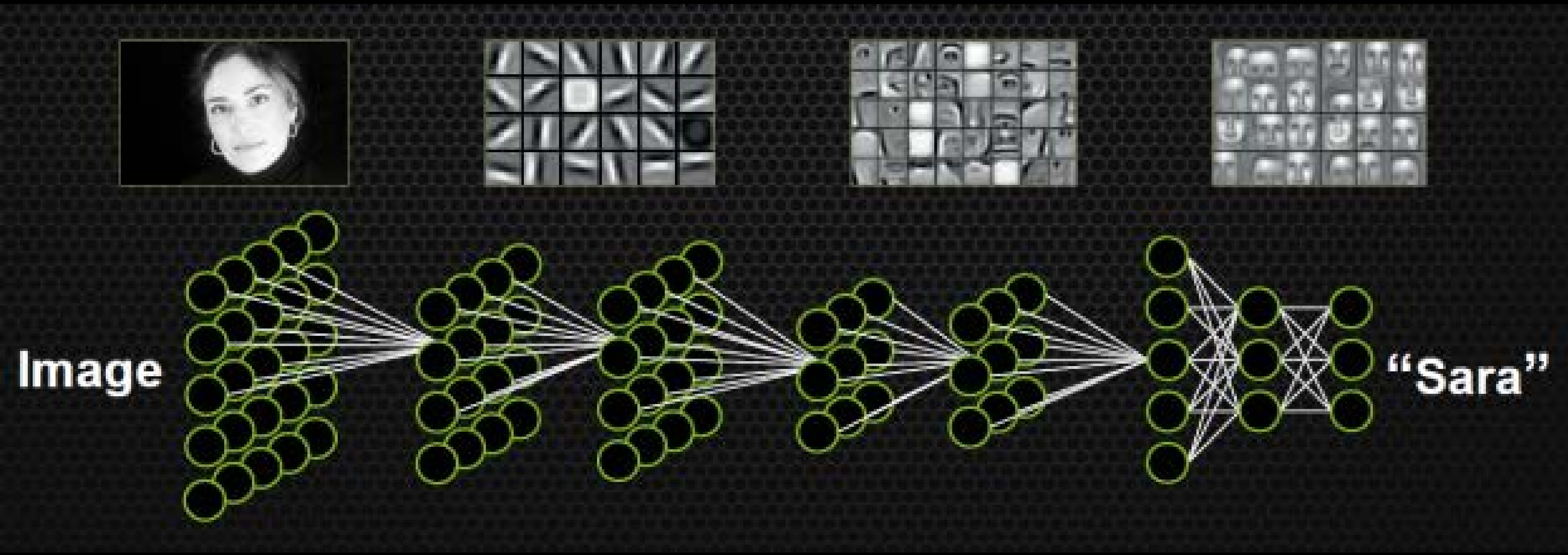


Detection rate

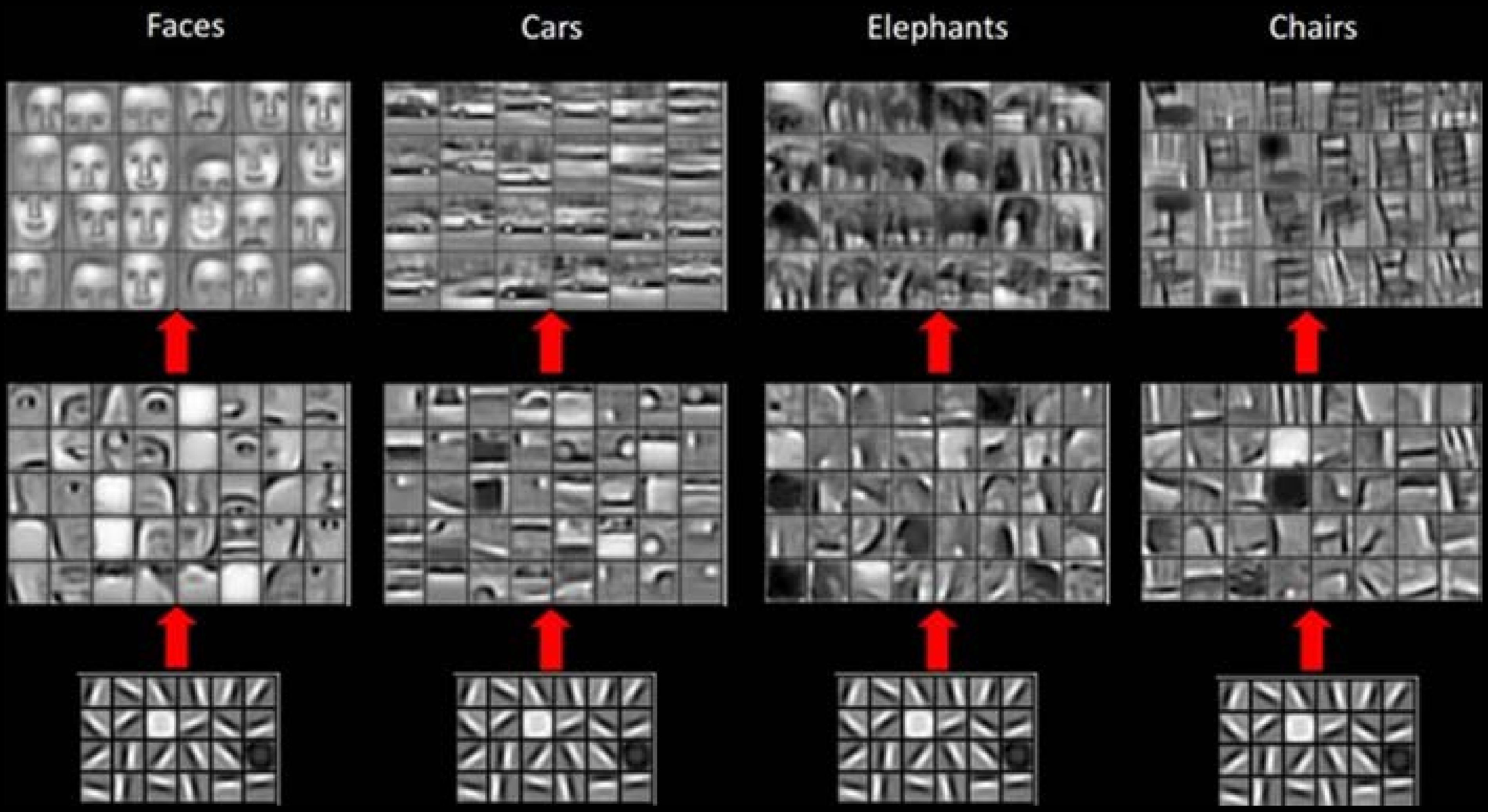


Szegedy *et al. ILSVRC* (2014)

Levels of abstraction in neural nets



http://blog.agi.io/



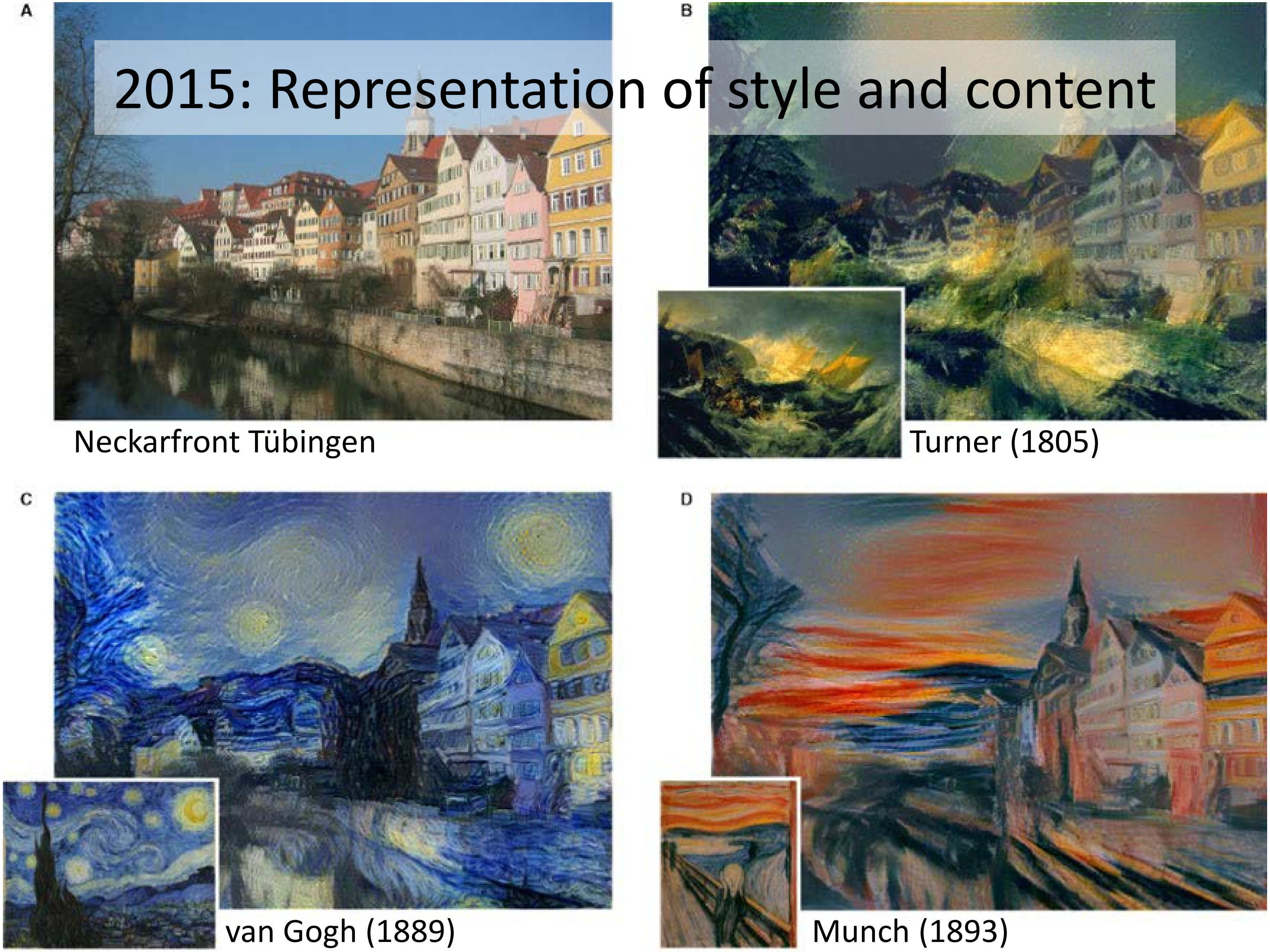
http://image.slidesharecdn.com/

2015: Image Captions

A refrigerator filled with lots of food and drinks.

Vinyals *et al. arXiv:1411.4555* (2015)

2015: Representation of style and content



Gatys *et al. arXiv:1508.06576* (2015)

2015: Inceptionism

Kevin Kwok. Youtube (2016)

Outline

1. Radiomics – Introduction
2. Machine Learning
3. Computer Vision
4. **Radiomics – Challenges ahead**

Radiology = Atari Game?

28,224 numbers per image

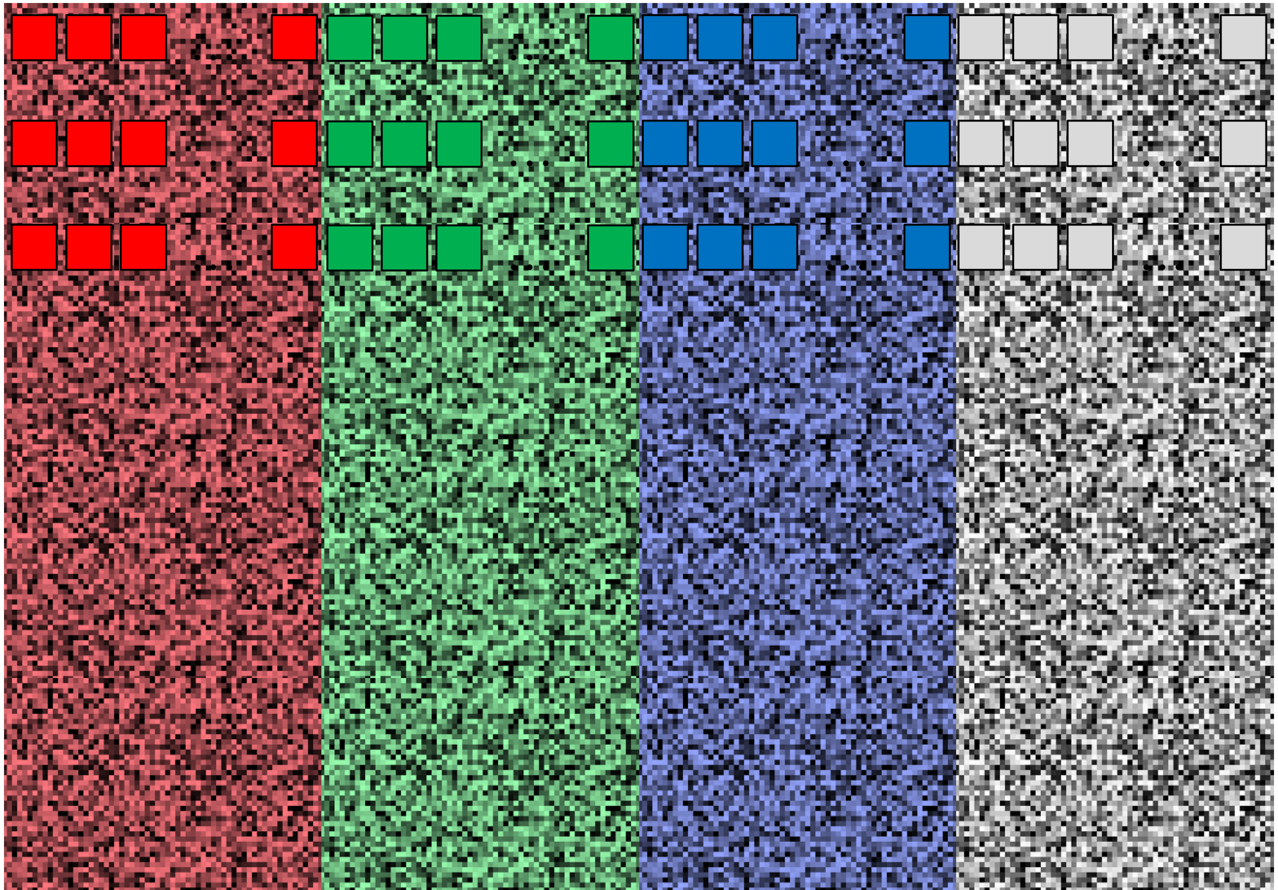
Image 1

Image 2

Image 3

…

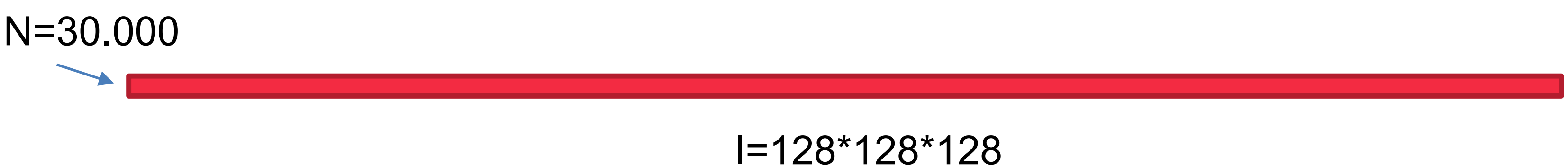
…



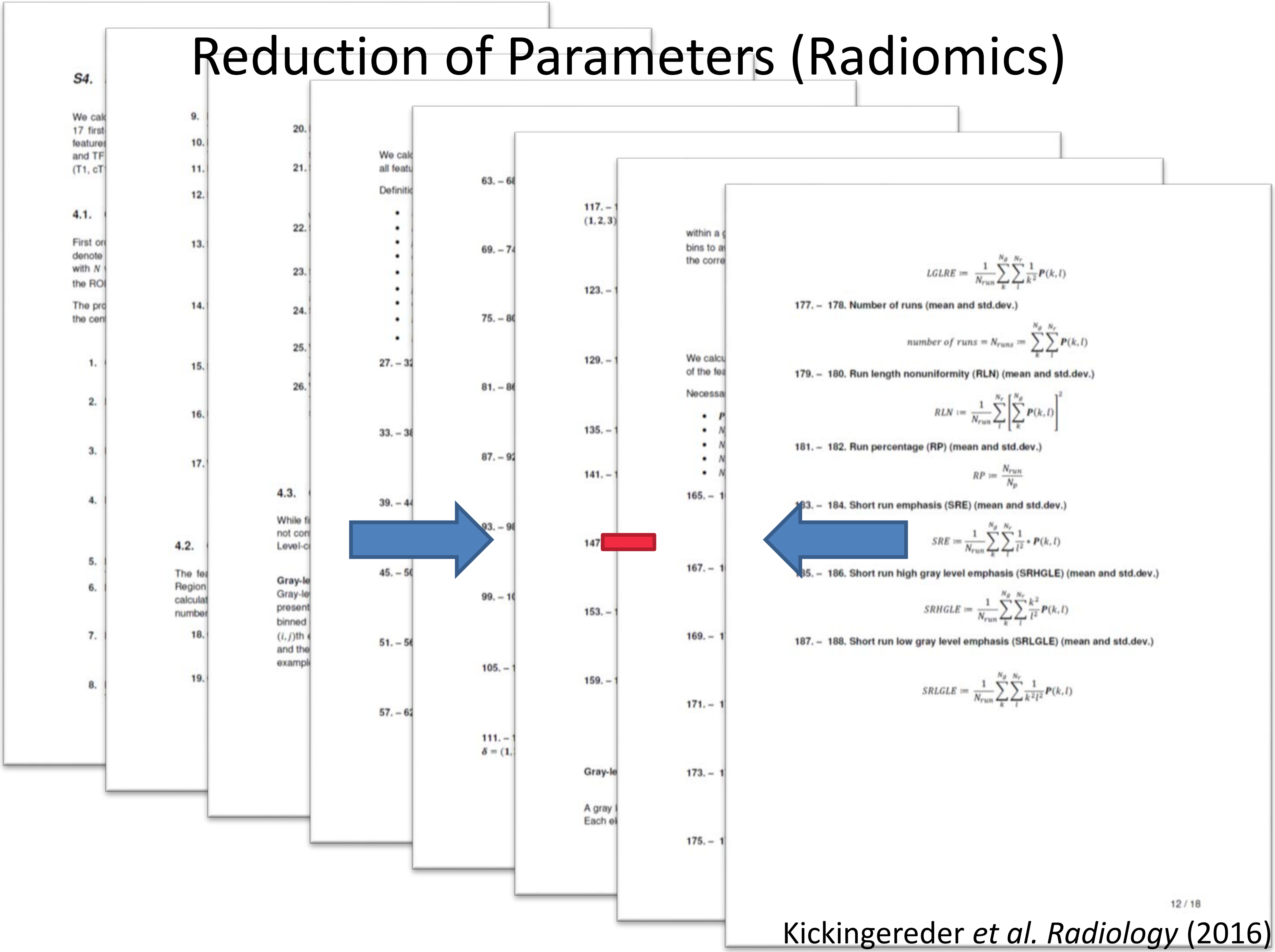
N = 50Mio
(1585 slides)

What about medical imaging?

Training data rare!



Reduction of Parameters (Radiomics)



$$LGLRE := \frac{1}{N_{run}} \sum_{k}^{N_g} \sum_{l}^{N_r} \frac{1}{k^2} \boldsymbol{P}(k,l)$$

177. – 178. Number of runs (mean and std.dev.)

$$number\ of\ runs = N_{runs} := \sum_{k}^{N_g} \sum_{l}^{N_r} \boldsymbol{P}(k,l)$$

179. – 180. Run length nonuniformity (RLN) (mean and std.dev.)

$$RLN := \frac{1}{N_{run}} \sum_{l}^{N_r} \left[\sum_{k}^{N_g} \boldsymbol{P}(k,l) \right]^2$$

181. – 182. Run percentage (RP) (mean and std.dev.)

$$RP := \frac{N_{run}}{N_p}$$

183. – 184. Short run emphasis (SRE) (mean and std.dev.)

$$SRE := \frac{1}{N_{run}} \sum_{k}^{N_g} \sum_{l}^{N_r} \frac{1}{l^2} \cdot \boldsymbol{P}(k,l)$$

185. – 186. Short run high gray level emphasis (SRHGLE) (mean and std.dev.)

$$SRHGLE := \frac{1}{N_{run}} \sum_{k}^{N_g} \sum_{l}^{N_r} \frac{k^2}{l^2} \boldsymbol{P}(k,l)$$

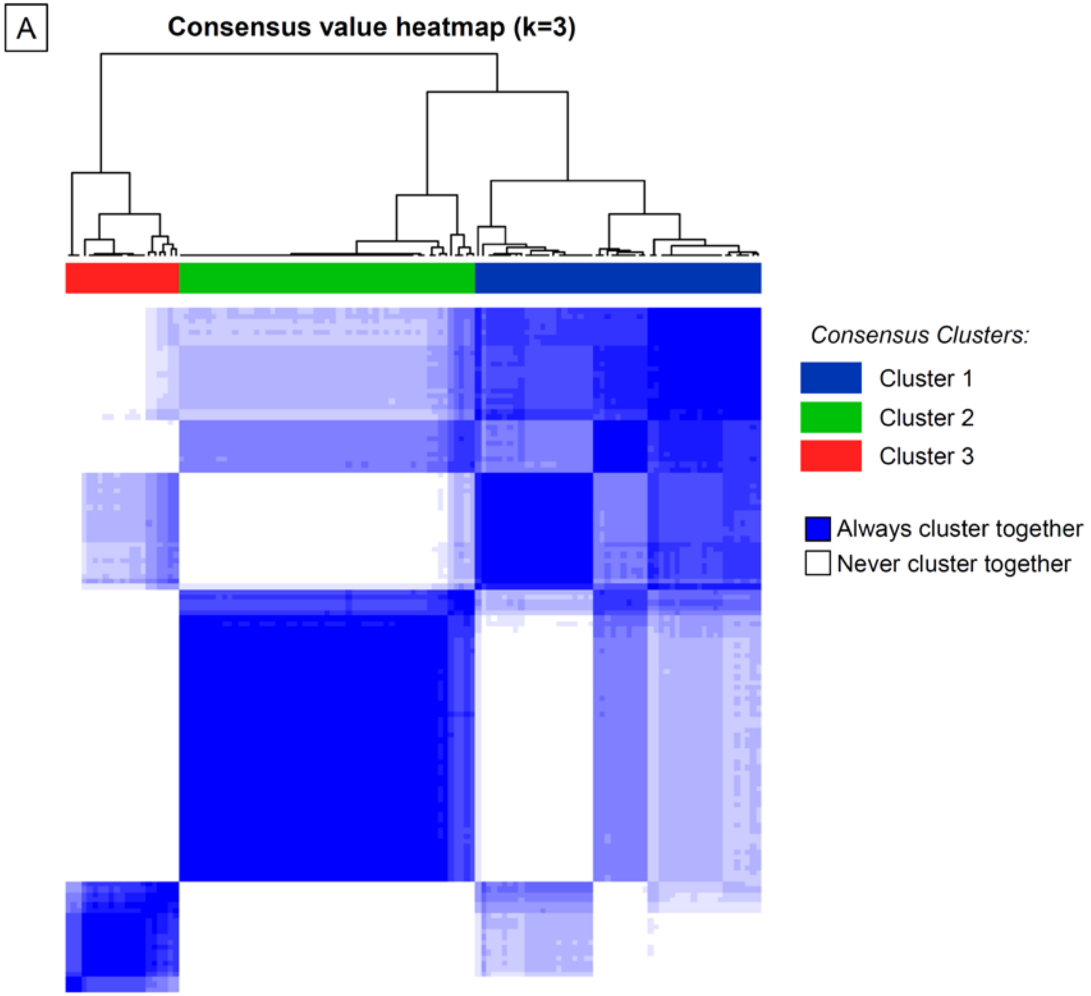
187. – 188. Short run low gray level emphasis (SRLGLE) (mean and std.dev.)

$$SRLGLE := \frac{1}{N_{run}} \sum_{k}^{N_g} \sum_{l}^{N_r} \frac{1}{k^2 l^2} \boldsymbol{P}(k,l)$$

12 / 18

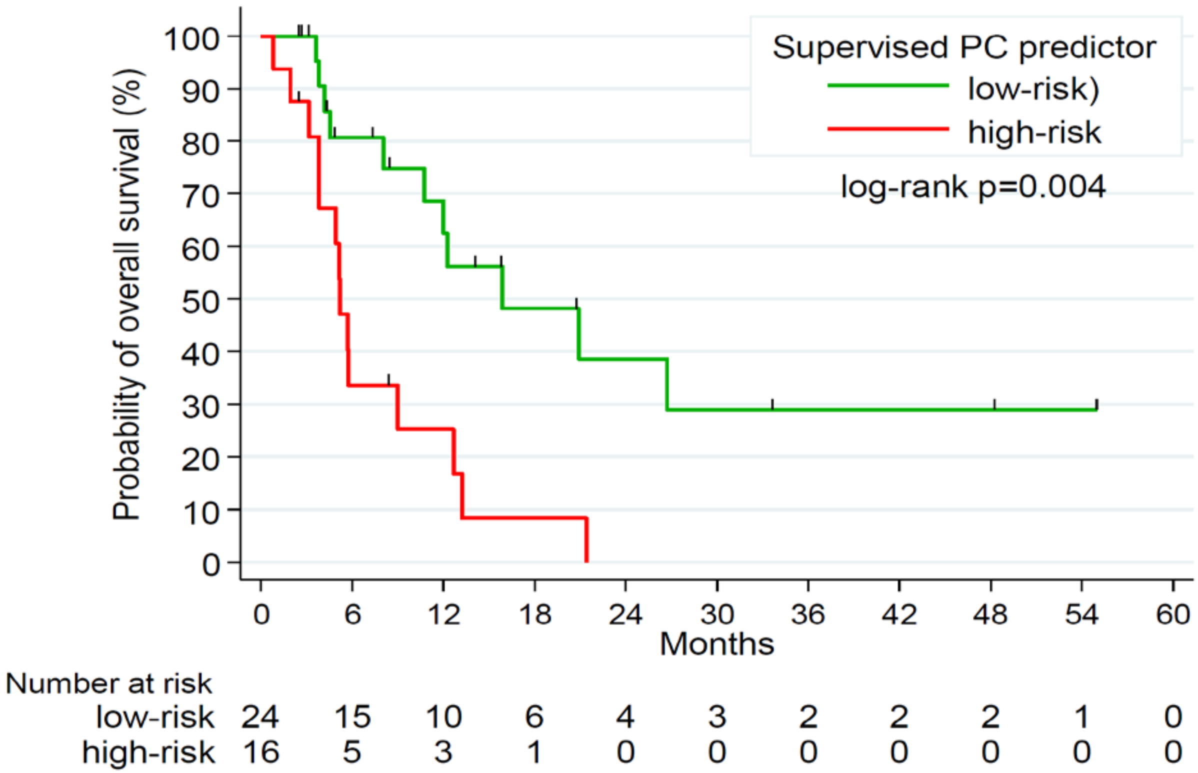
Kickingereder *et al. Radiology* (2016)

Predicting antiangiogenic treatment response in glioblastoma



Kickingereder *et al. Radiology* (2016)

Prediction of therapy response in brain tumors



Kickingereder *et al.* Radiology (2016)

Challenges ahead

- Capture
- Manage
- Process
- Share
- Integrate
- Analyze
- Interpret

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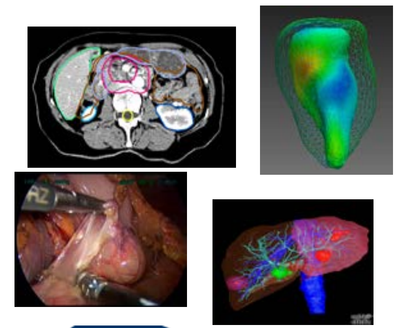

XNAT:
- Study collections
- Study objects
- Imaging sessions
- Annotations

Challenges ahead

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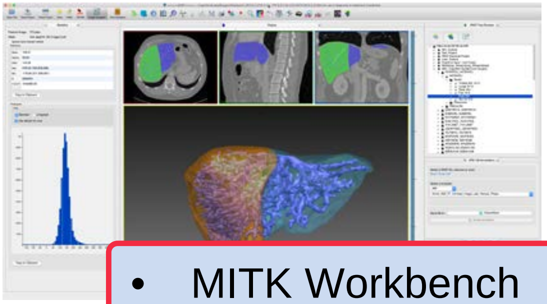


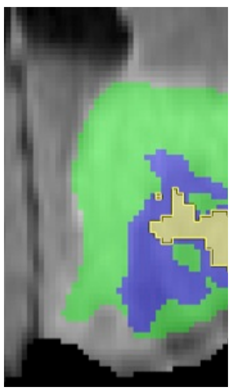
- MITK Workbench
- CTK Command Line
- Python Scripting

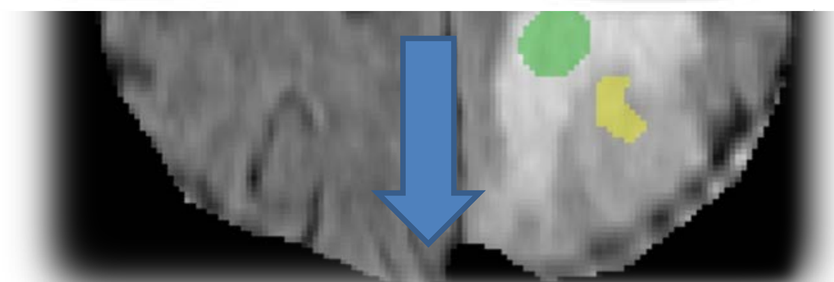
XNAT:
- Study collections
- Study objects
- Imaging sessions
- Annotations

Each pixel one observation

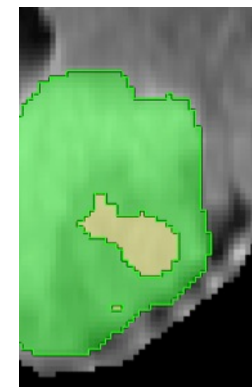
TRANSFER OF LEARNING

Expert



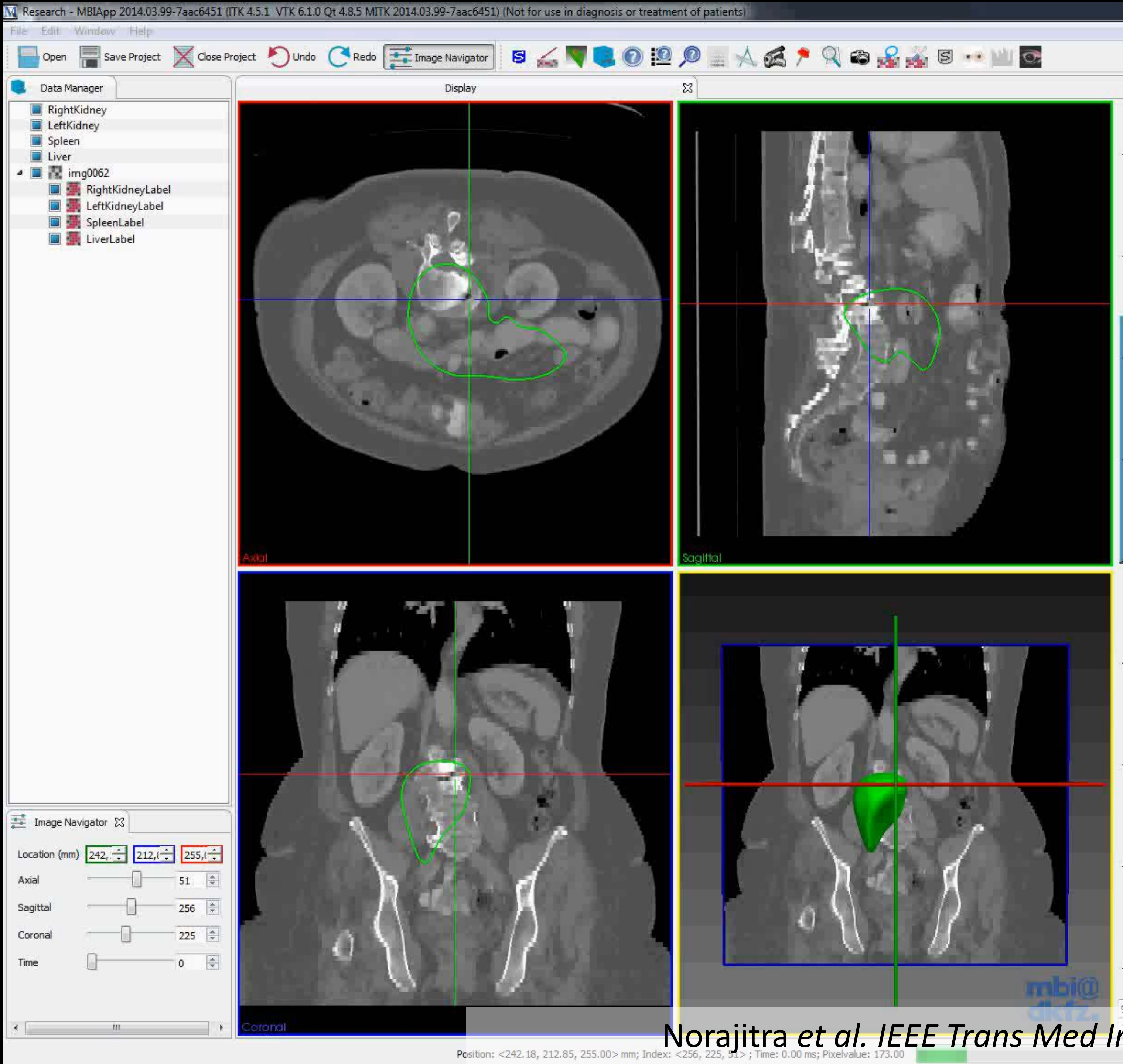


Expert 2



- Edema
- Active tumor
- Contrat-enhanced

Götz *et al. IEEE Trans Med Img* (2015)



Norajitra *et al. IEEE Trans Med Img* (2016)

Challenges ahead

- Capture
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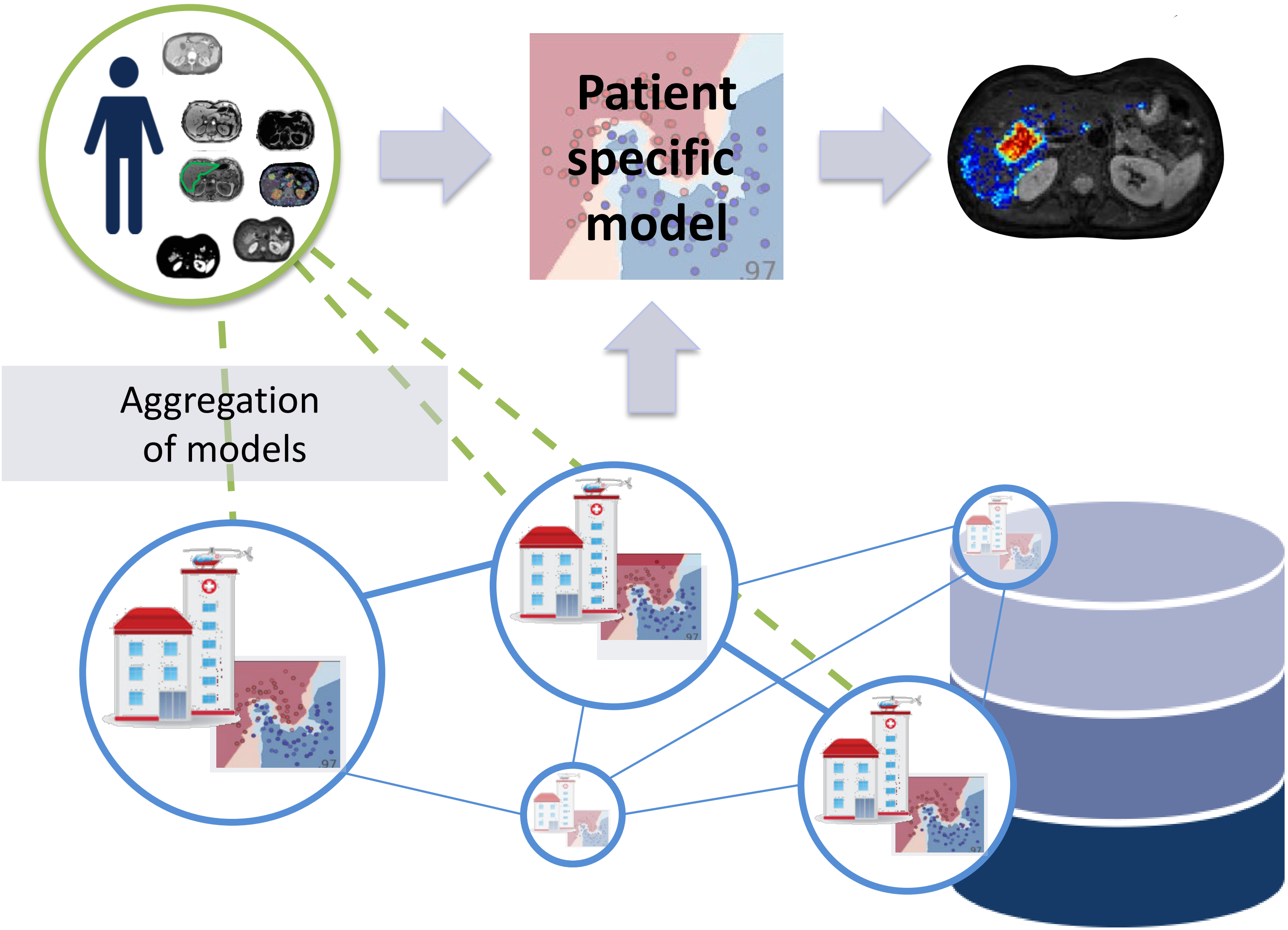
- Interpret

Distributed knowledge



Klaus H. Maier-Hein
Medical Imaging Computing Group

Challenges ahead

- Capture
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Challenges ahead

- Capture
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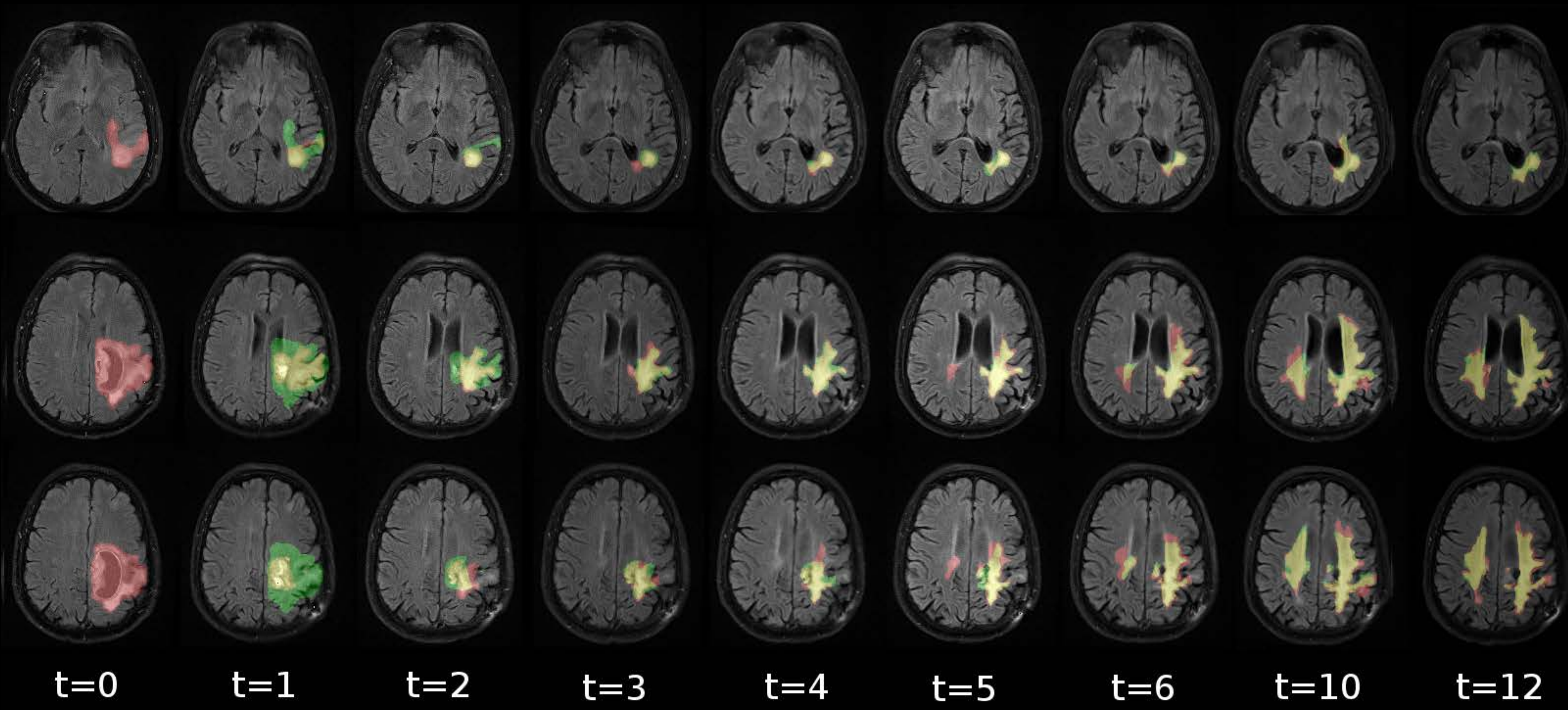
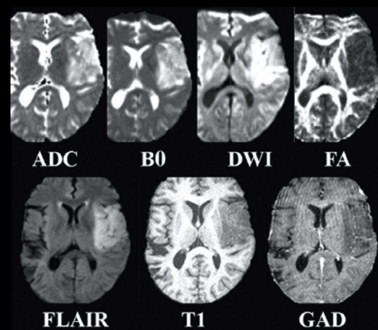
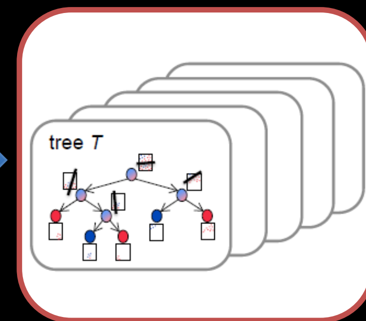
Prognostic models?

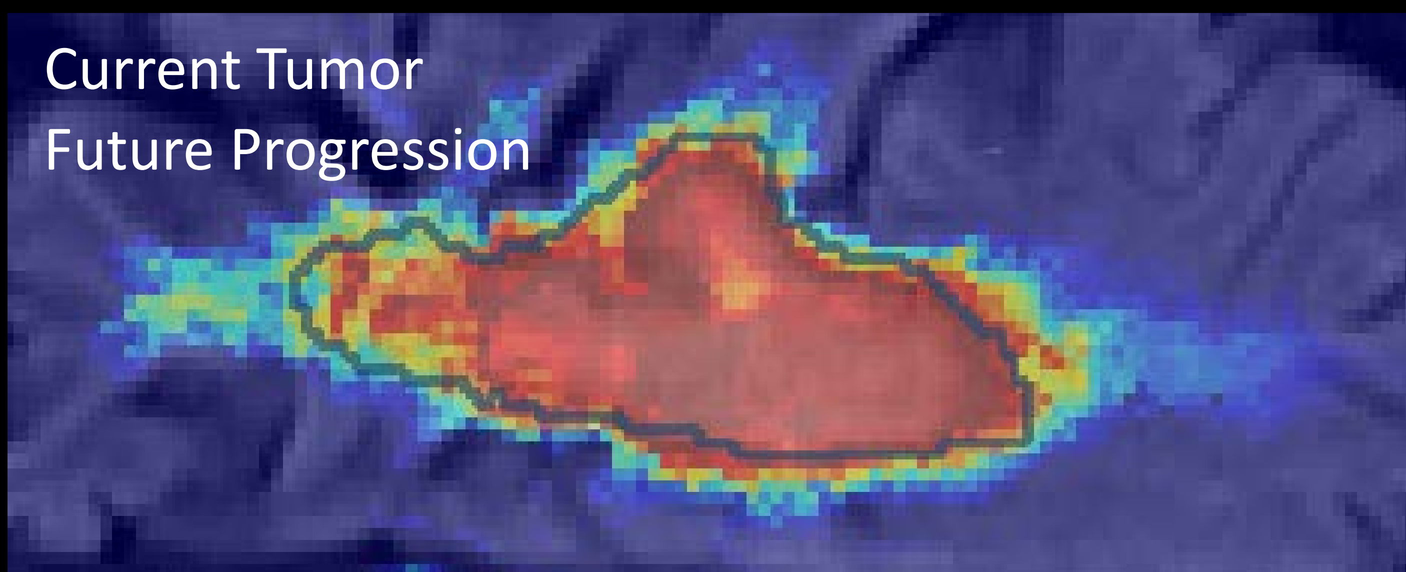


- Weber et al..Tumor Progression Mapping: An Intuitive Visualization of Glioblastoma Progression in MR Follow-ups. ISMRM (2014)

Machine learning & disease mechanisms







- Unpublished data: Weber et al. Individual estimation of brain tumor invasion margin using data-driven glioma growth models. (in preparation)

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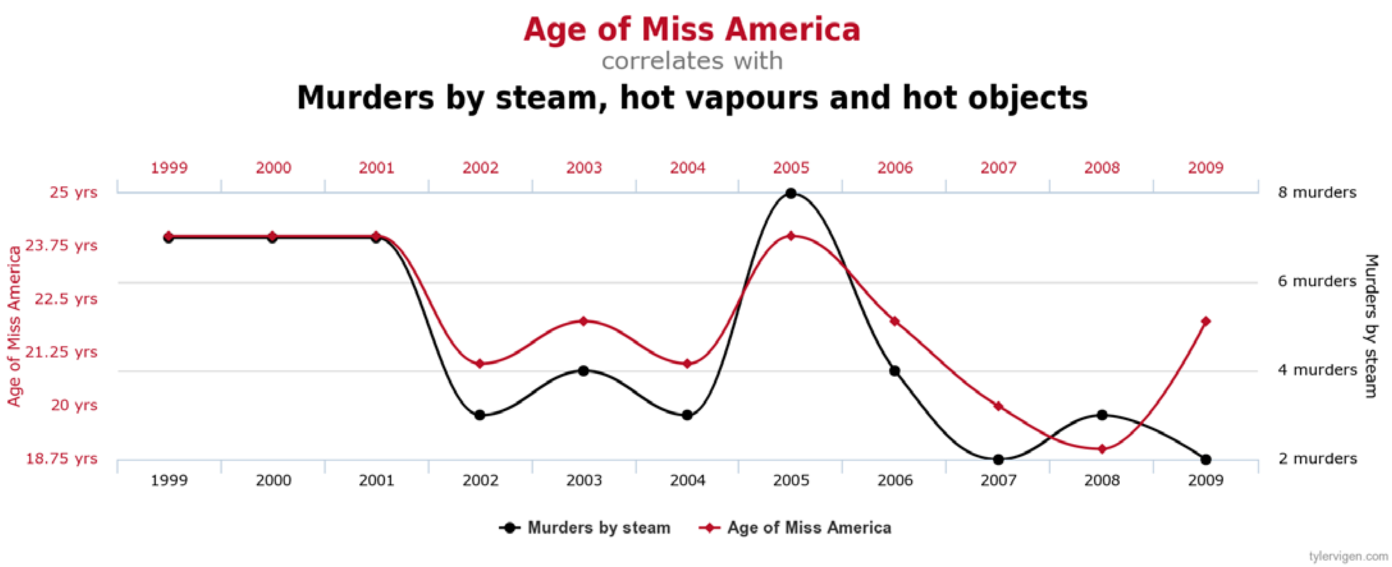
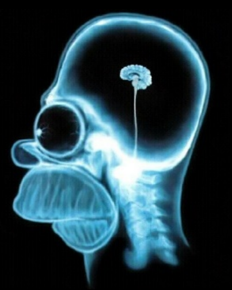
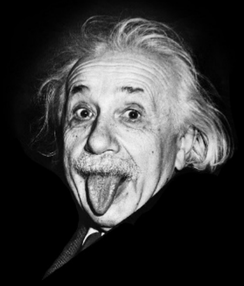
Is the scientific method itself becoming obsolete?

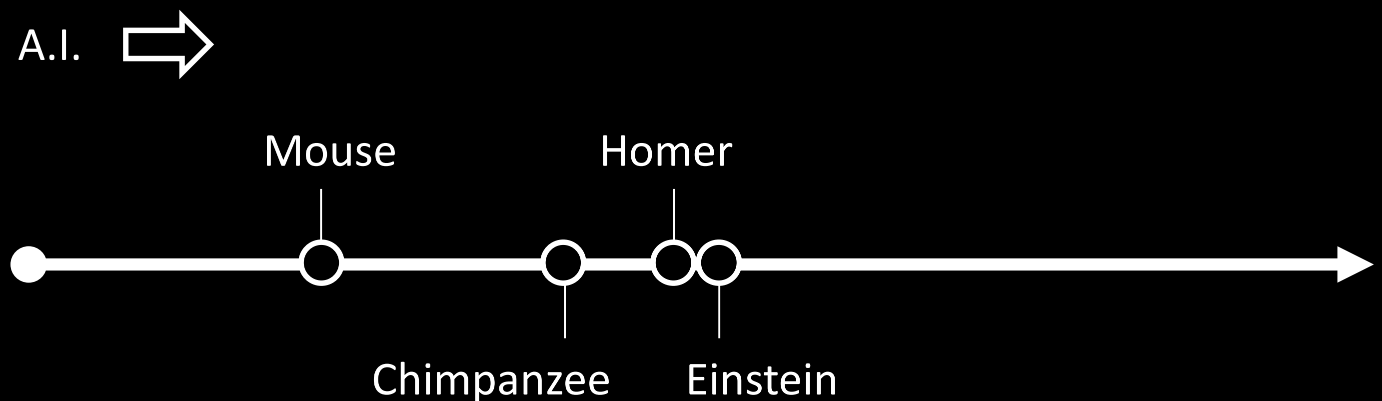
- False alarms may increase when one can measure more things
- Does not replace randomized clinical trials and other experimental designs



Intelligence

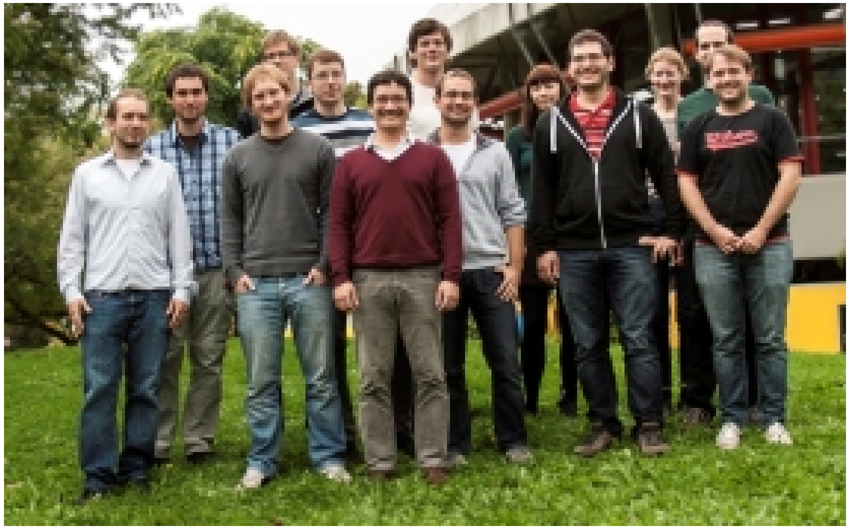






Nick Bostrom, Philosoph, Oxford University.

Thank you!



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Alex Leemans et al., Utrecht

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Collaborators @Uni/NCT Heidelberg
Collaborators @KIT Karlsruhe
Collaborators @IWR Heidelberg
Collaborators @SFB/Transregio 125

The MITK team
The MBI team