Intelligenza artificiale in medicina nucleare

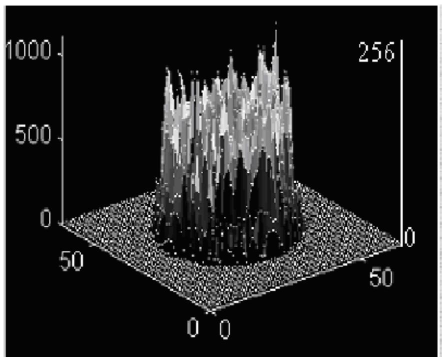
Dott. Stelvio Sestini SOC Medicina Nucleare Prato

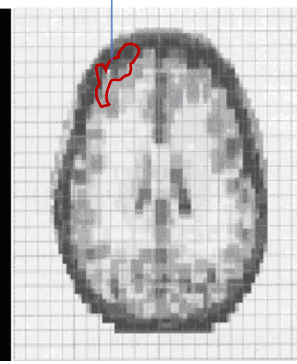
Artificial Intelligence in Nuclear Medicine

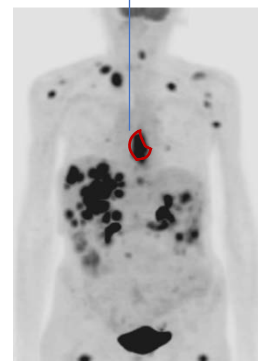
Felix Nensa1, Aydin Demircioglu1, and Christoph Rischpler2

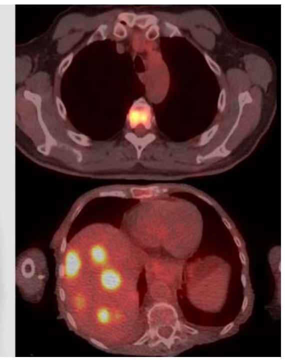
J Nucl Med 2019; 60:29S–37S
DOI: 10.2967/jnumed.118.220590

1) What do we measure : the 4^ dimension [$C_{radioligand}$] / time [$\Delta t_{0\text{ - Equilibrium}}$] in volume of interest (V_{xyz})

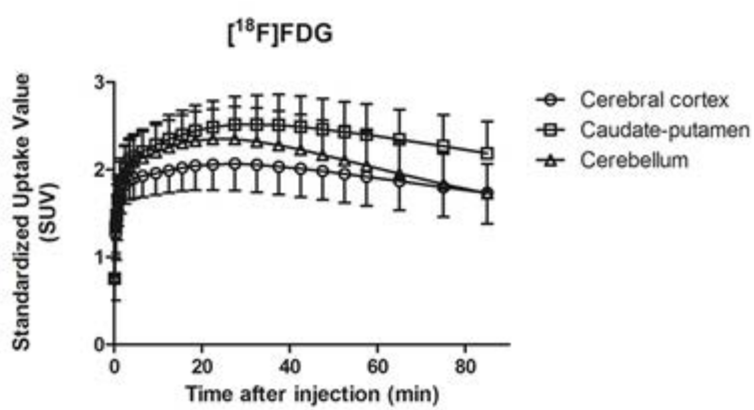








Time Activity Curve



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2) AI: Symbolic reasoning

the only one AI during From the 1950s to the 1980s,

We model entities of the real world and their logical relationships in the form of symbols with which arithmetic operations can then be performed.

Already using so far !!

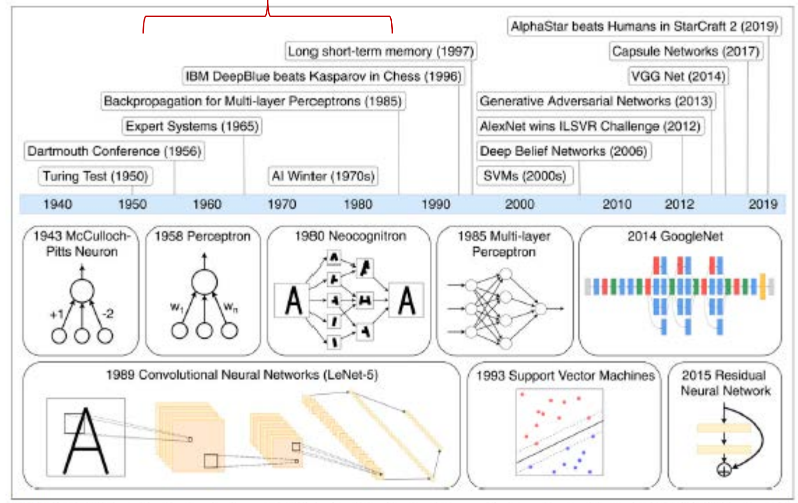


FIGURE 1. Brief time line of major developments in AI and machine learning. Some methods are also depicted symbolically. ILSVR = ImageNet Large Scale Visual Recognition; SVMs = support vector machines; VGG = Visual Geometry Group.

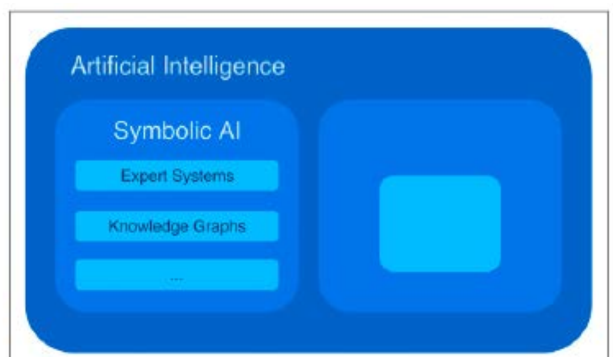
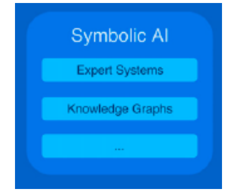
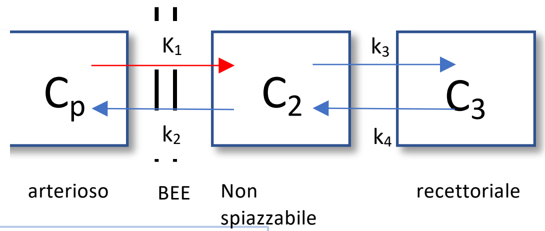


FIGURE 2. Division of field of AI into symbolic AI and machine learning, of which deep learning is a branch.

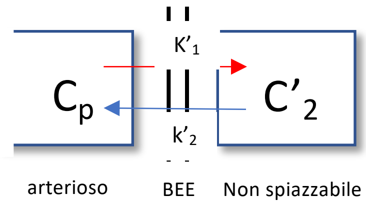
AI: Example - Compartmental Modelling in Nuclear Medicine



a - Tessuto CONTENENTE i recettori
(Tessuto con il parametro da misurare)



b - Tessuto che NON contiene i recettori
(Tessuto di Riferimento)



Le variazioni di [C] nei singoli compartimenti possono essere descritte con un *set di equazione differenziali* che tiene conto degli input/output nei compartimenti stessi:

a

Eq. 4 $\frac{dC_3(t)}{dt} = k_3C_2(t) - k_4C_3(t)$

Eq. 5 $\frac{dC_2(t)}{dt} = K_1C_p(t) - k_2C_{2(t)} - k_3C_2(t) + k_4C_3(t)$

b

Eq. 6 $\frac{dC'_2(t)}{dt} = K_1C_p(t) - k'_2C'_2(t)$

Eq. 7 $0 = k_3C_2(t) - k_4C_3(t)$ → Eq. 10 $\frac{C_3}{C_2} = \frac{k_3}{k_4}$ e sostituendo $C_2 = \frac{C_3k_4}{k_3}$ in Eq. 8

Eq. 8 $0 = K_1C_p(t) - k_2C_{2(t)} - k_3C_2(t) + k_4C_3(t)$ → Eq. 11 $\frac{C_3}{f_1Cp} = \frac{K_1k_3}{k_2k_4}$ dove BP = $\frac{C_3}{f_1Cp}$ ≈ $\frac{B'_{max}}{K_d}$ in vitro

Eq. 9 $0 = K'1Cp(t) - k'_2C'_2(t)$ → Eq. 12 $\frac{C'_2}{f_1Cp} = \frac{K'1}{k'_2}$

All'Equilibrio (no trasferimento netto di radiofarmaco tra i comp.), il lato sn delle equazioni = 0

Legenda

$C_P(t)$ = [plasmatica] del radiofarmaco non metabolizzato (Bq/mL)
$C_2(t)$ = [radiofarmaco] nel comp. non spiazzabile del tessuto con i recettori (Bq/mL)
$C'_2(t)$ = [radiofarmaco] nel comp. non spiazzabile del tessuto di riferimento (Bq/mL)
$C_3(t)$ = [radiofarmaco] nel comp. recettoriale specifico (Bq/mL)

$f_1C_p(t)$ = frazione di C_p che può diffondere verso C_2 o C'_2
$f_1C_2(t)$ = frazione di C_p che può diffondere verso C_3
K_1 e K'_1 = Delivery Rate Constant dal plasma al comp. non spiazzabile (mL/g/min)
k_2 e k'_2 = rate di retro-diffusione dal comp. non spiazzabile al comp. plasmatico (min^{-1})
K_3 e k_4 = rate di trasferimento dal comp.non spiazzabile al comp. Recettoriale e viceversa (min^{-1})

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3) AI: MACHINE LEARNING – DEEP LEARNING

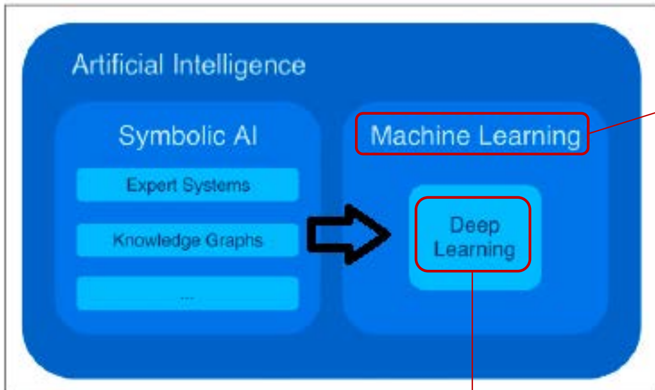


FIGURE 2. Division of field of AI into symbolic AI and machine learning, of which deep learning is a branch.

In "conventional machine learning" computer systems learn to accomplish a task <u>independently</u>—that is, without explicit instructions—and thus perform observational learning from large amounts of data.

Warning

… big data are necessary to learn

deep learning is based on artificial neural networks (ANNs). Because of a multitude of layers (so-called hidden layers) between the input and output layers, these neural networks have a much larger space for **<u>free parameters and thus allow much more complex abstractions</u>** than conventional machine learning methods.

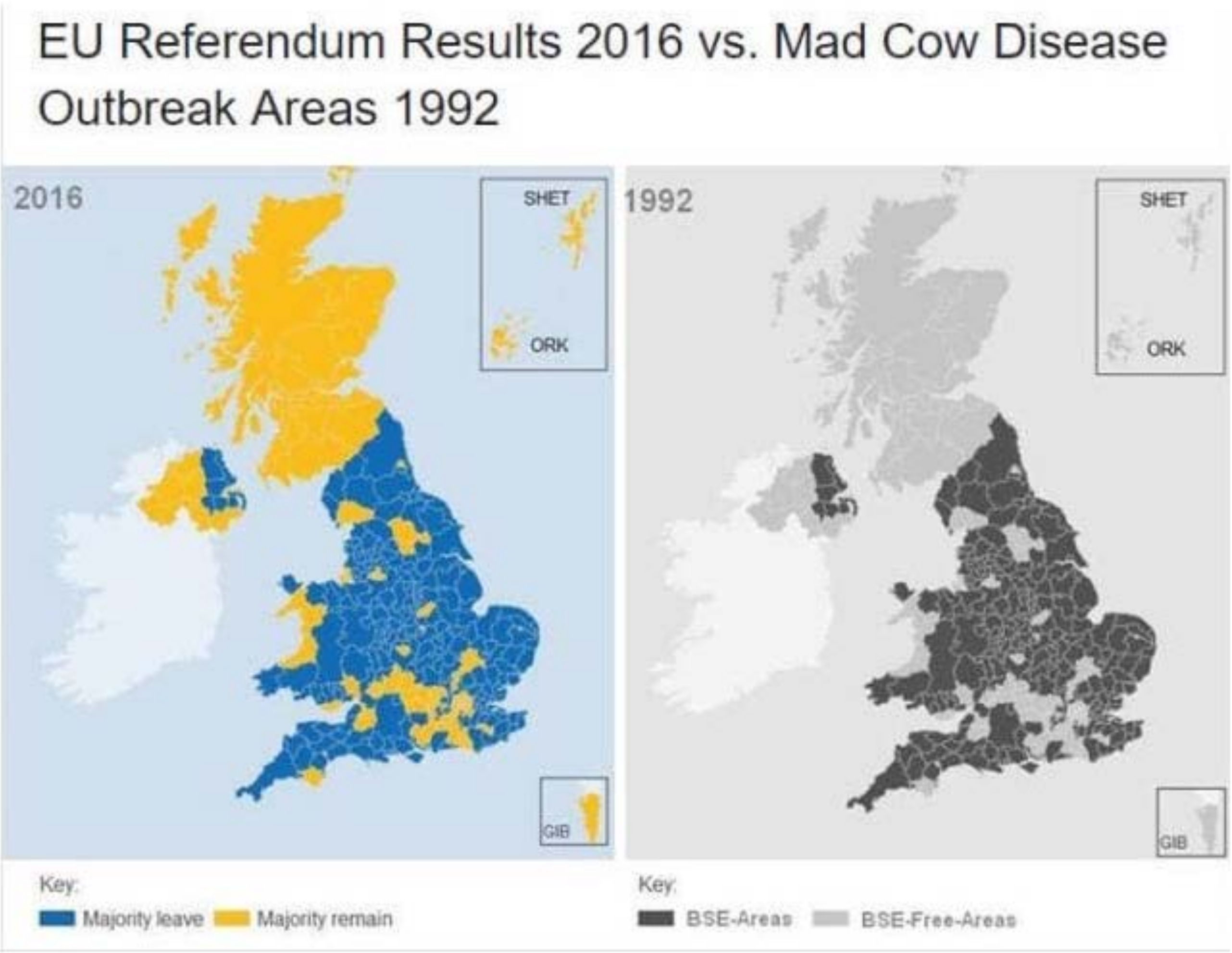
… the internal representation of the investigated system is very complex as "black boxes," and the corresponding output of such systems can no longer be reliable

Warning

… to be aware of question in input

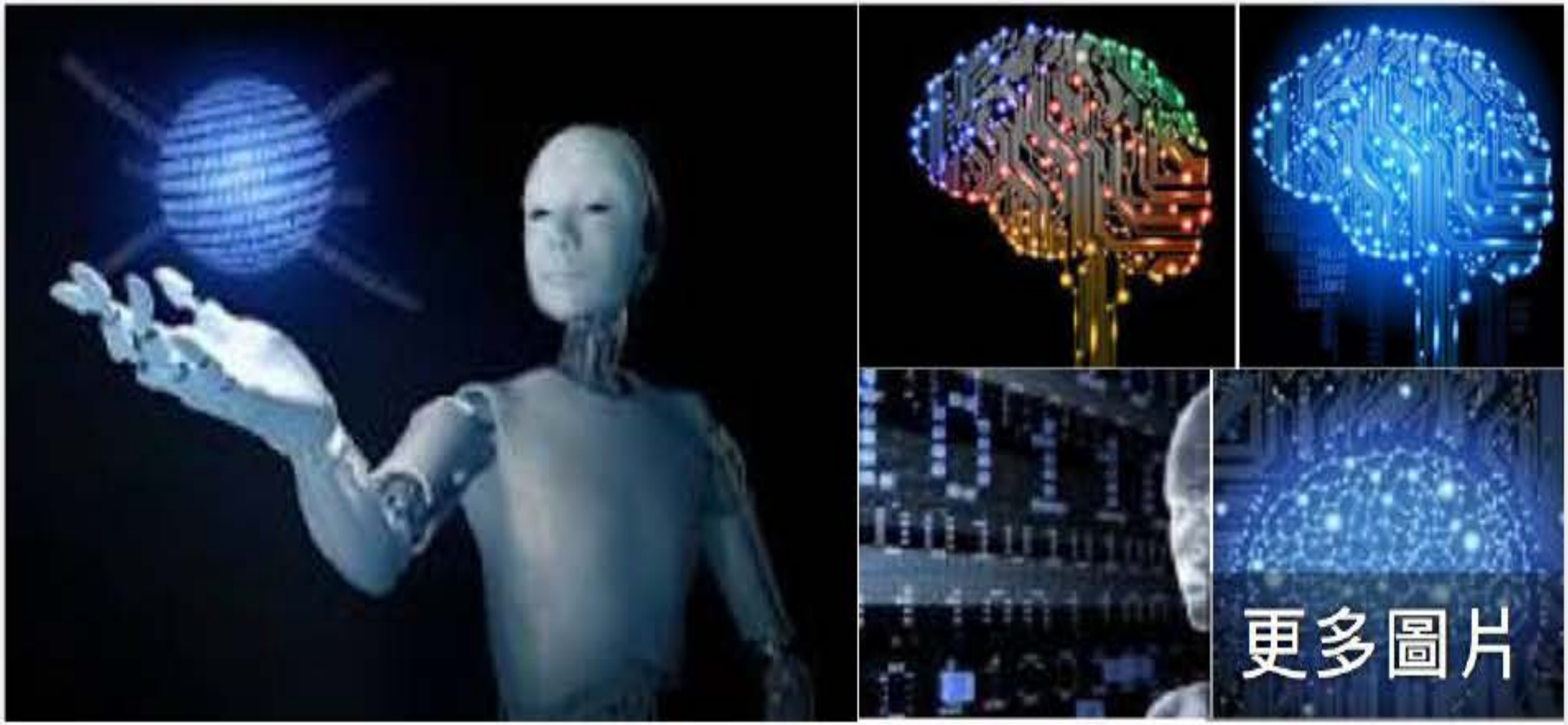
Warning

… to be aware of question in input …



Intelligenza Artificiale in Medicina Nucleare

Fisica Sanitaria PO - PT



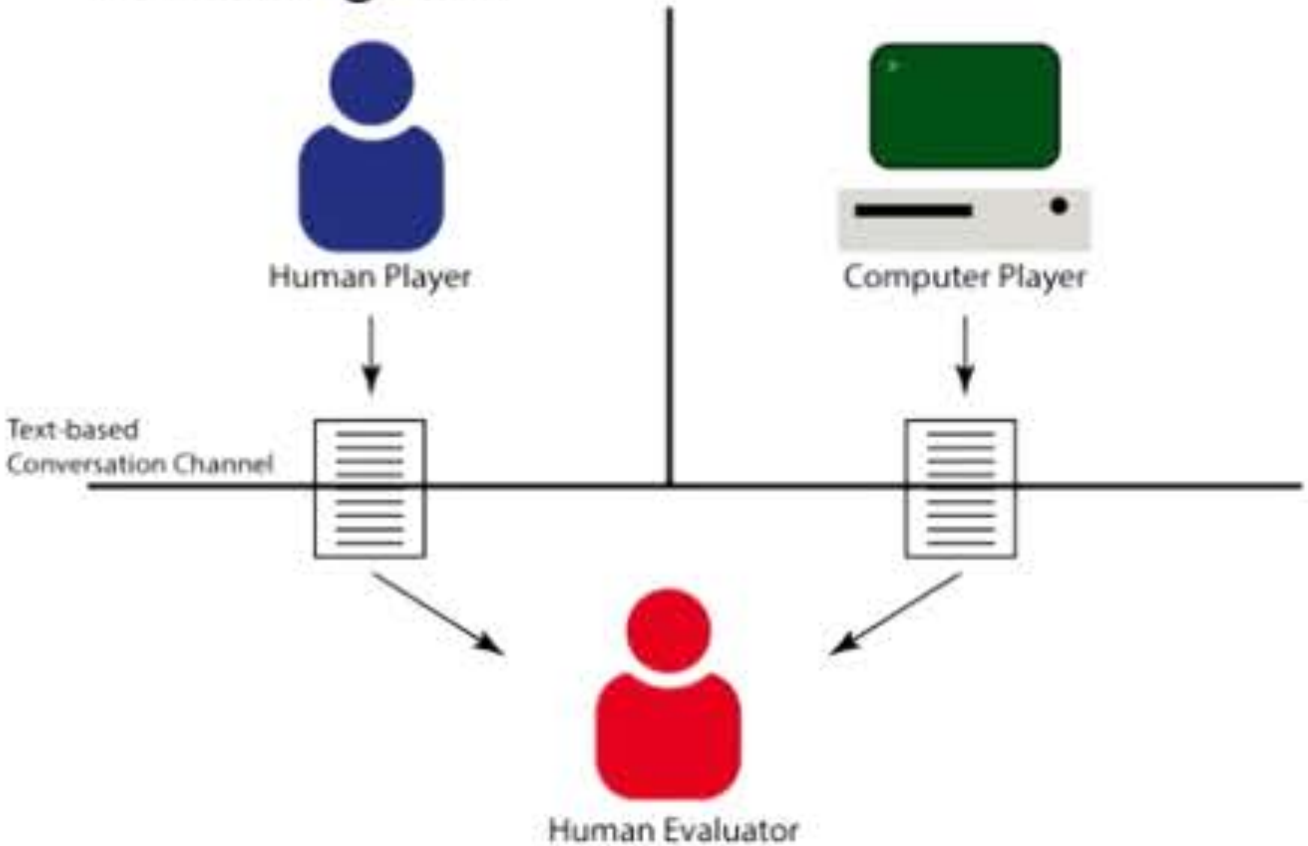
Artificial intelligence (AI) is intelligence exhibited by machines.

…

Colloquially, the term "artificial intelligence" is applied when a machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving".

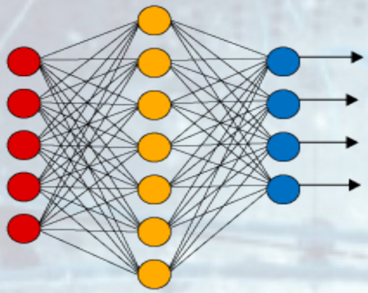
Can Machines Think?

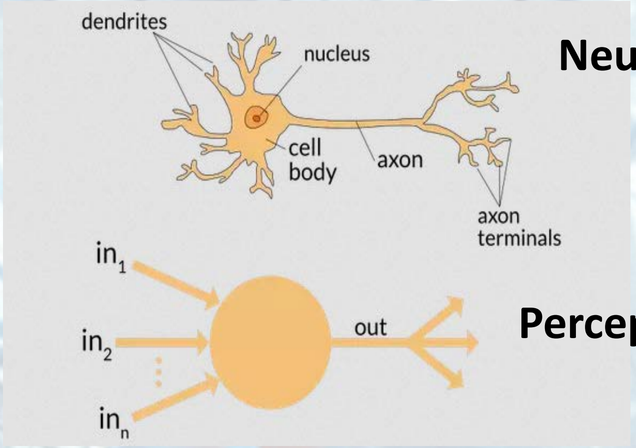
- The Turing Test



Turing AM. *Mind*. 1950;59:433-460.
Warwick K and Shah H. *J Exp Theor Artif Intell*. 2016;28:989-1007.

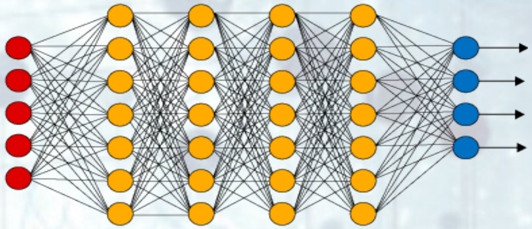
From Neural Network to Deep Learning





Neuron

Perceptron

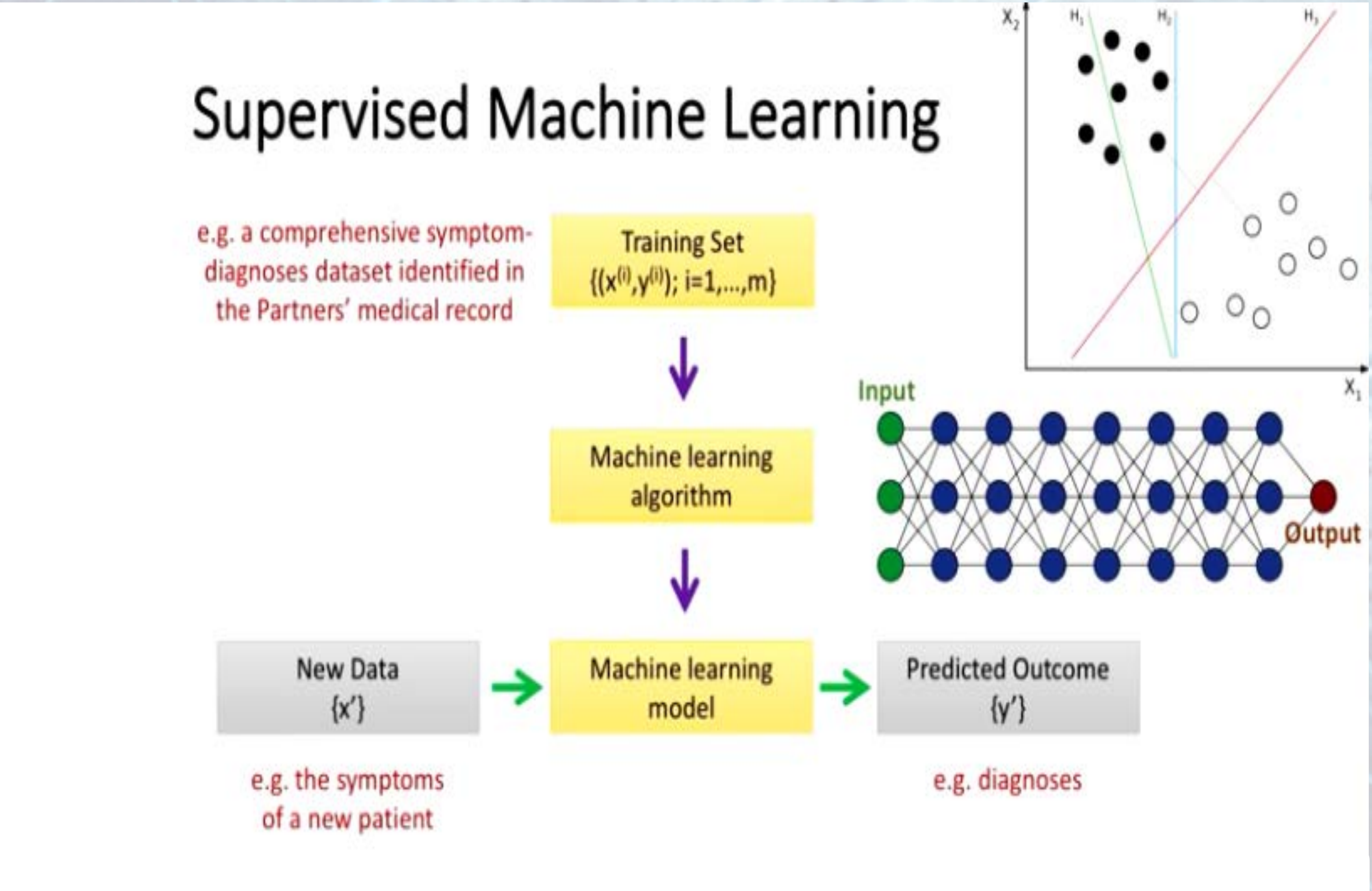


Application Areas

system identification, natural resource management, process control, vehicle control, quantum chemistry, decision making, game playing, face identification, pattern recognition , signal classification, sequence recognition, object recognition, finance, **medical diagnosis**, visualization, data mining, machine translation, email spam filtering, social network filtering

Automatic speech recognition, Image recognition, visual art processing, Natural language processing, drug discovery and toxicology, customer relationship management, recommendation engines, Mobile advertising, **medical prognosis,** bioinformatics, Image restoration etc.

From Neural Network to Deep Learning

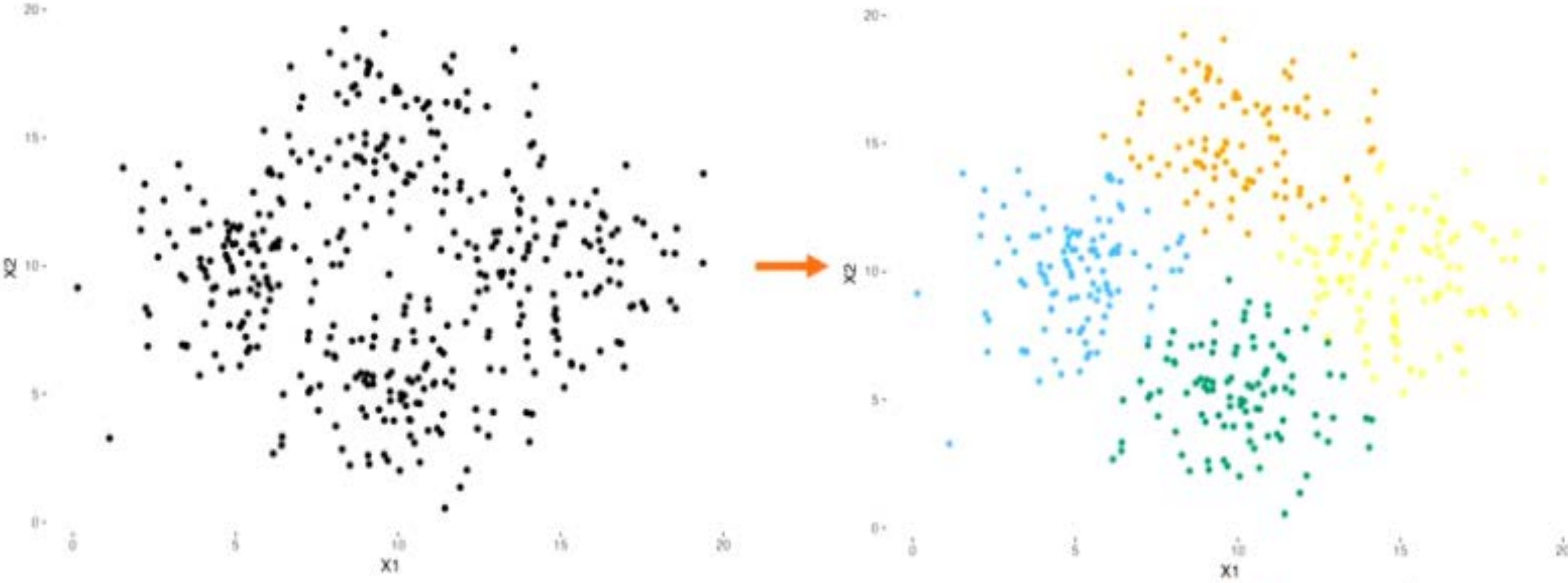


Yu KH et al. *Nat Biomed Eng*. 2018 (in press).

From Neural Network to Deep Learning

Unsupervised Machine Learning

- e.g. Clustering



Yu KH et al. *Nat Biomed Eng*. 2018 (in press).

From Neural Network to Deep Learning

Artificial Intelligence

- The field of study that attempts to both understand and build intelligent entities
- Fueled by
  - Availability of the big data
  - Advanced machine learning algorithms
  - Growth in computation power

2018

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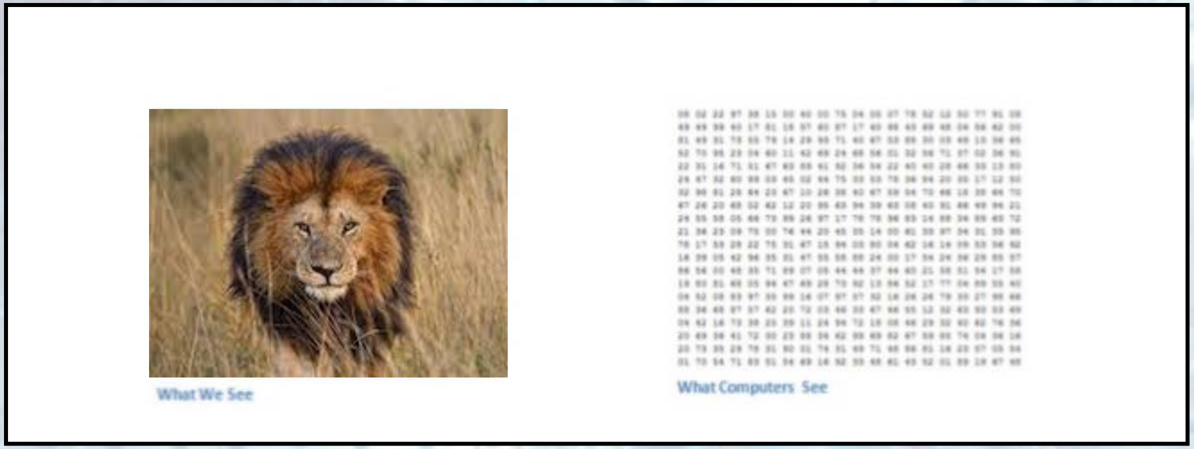
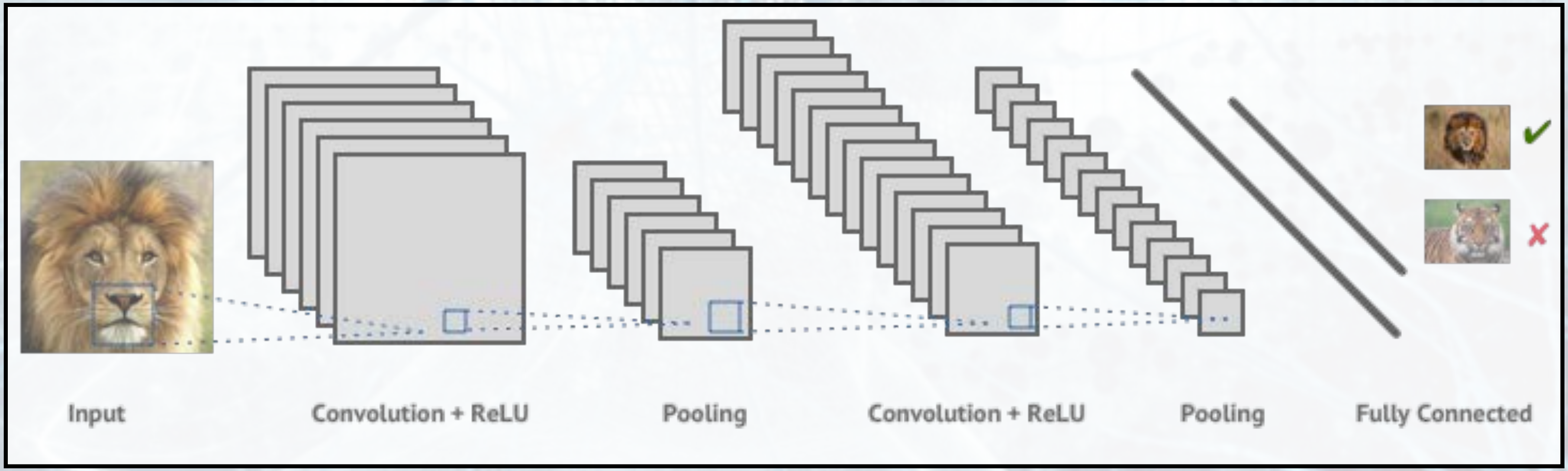
2006

From Neural Network to Deep Learning





"Every biopsy should be considered a failed imaging experiment"

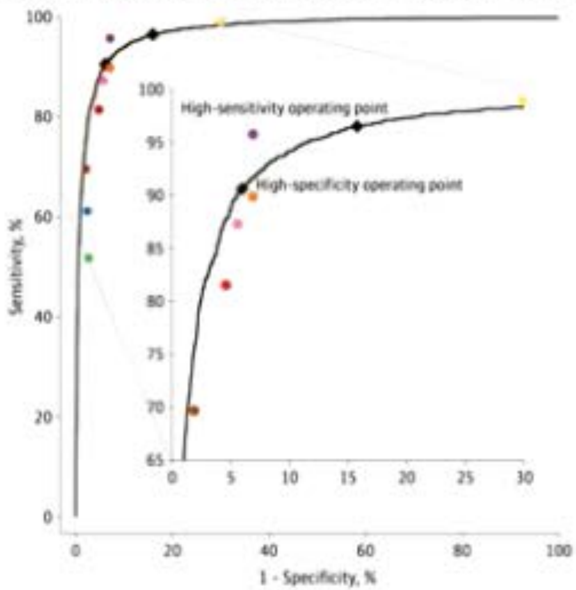
Mark Griswold, 2018

DL in Medicine

JAMA | Original Investigation | INNOVATIONS IN HEALTH CARE DELIVERY

Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs

Varun Gulshan, PhD; Lily Peng, MD, PhD; Marc Coram, PhD; Martin C. Stumpe, PhD; Derek Wu, BS; Arunachalam Narayanaswamy, PhD; Subhashini Venugopalan, MS; Kasumi Widner, MS; Tom Madams, MEng; Jorge Cuadros, OD, PhD; Ramasamy Kim, OD, DNB; Rajiv Raman, MS, DNB; Philip C. Nelson, BS; Jessica L. Mega, MD, MPH; Dale R. Webster, PhD



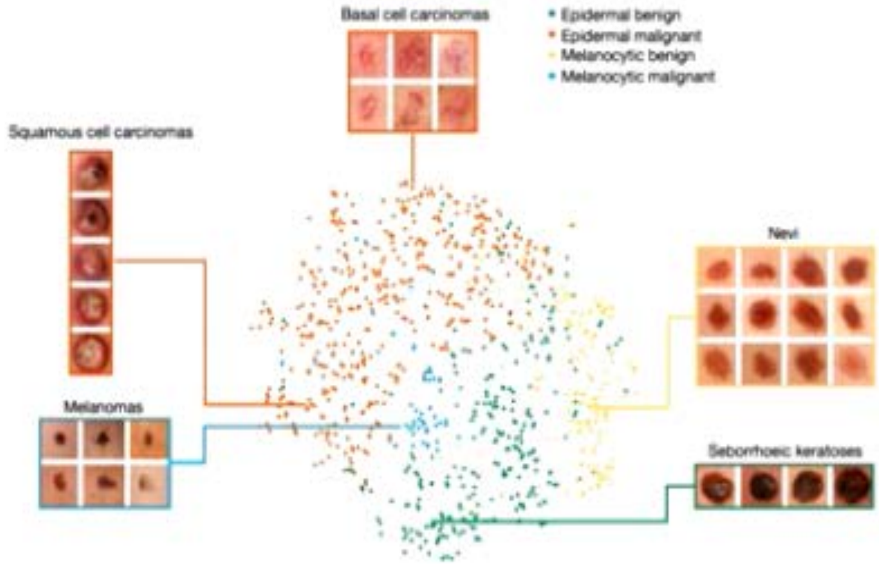
- A deep neural network model detects referable diabetic retinopathy with expert-level performance
- A similar system by another group is approved by the U.S. FDA

Gulshan V et al. *JAMA*. 2016 Dec 13;316(22):2402-2410.

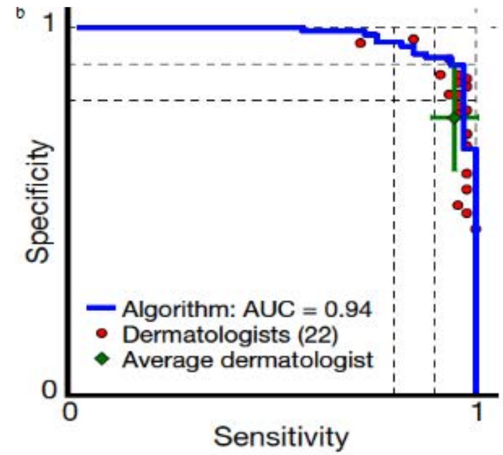
DL in Medicine

Dermatologist-level classification of skin cancer with deep neural networks

Andre Esteva[1*], Brett Kuprel[1*], Roberto A. Novoa[2,3], Justin Ko[2], Susan M. Swetter[2,4], Helen M. Blau[5] & Sebastian Thrun[6]



- Machine learning models accurately classified skin lesion images into 2,032 diagnoses



Esteva A et al. *Nature*. 2017 Feb 2;542(7639):115-118.

DL in Medicine

A Recurrent CNN for Automatic Detection and Classification of Coronary Artery Plaque and Stenosis in Coronary CT Angiography

Majd Zreik, Robbert W. van Hamersvelt, Jelmer M. Wolterink,
Tim Leiner, Max A. Viergever, Ivana Išgum

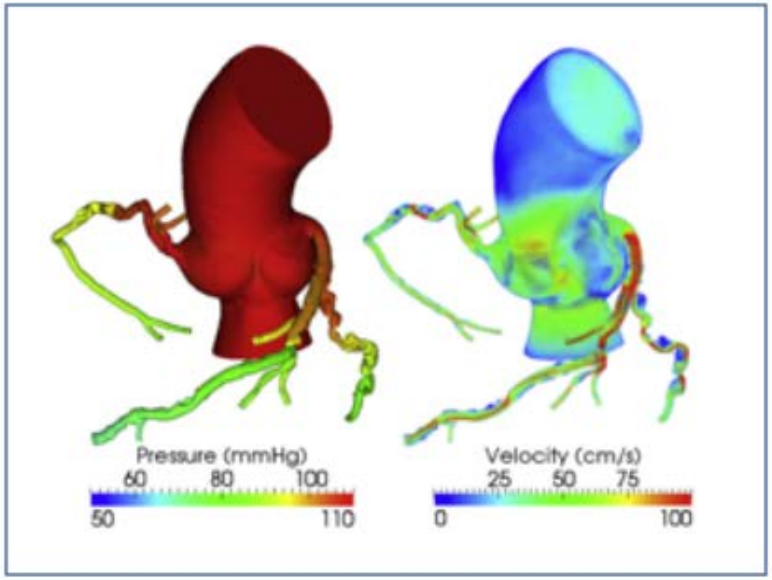


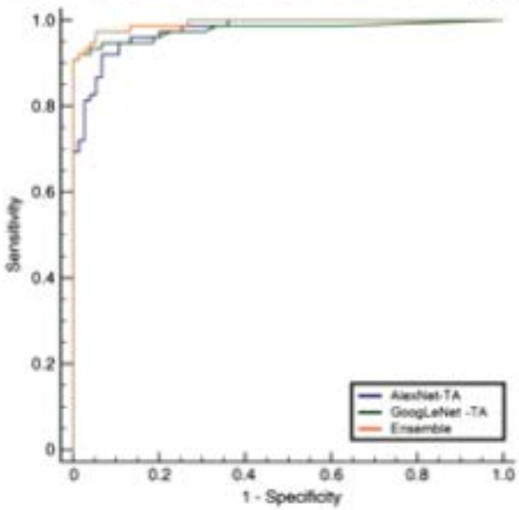
Figure 4: Three-dimensional pressure and velocity fields at one point in the cardiac cycle using FFR- based on CTA imaging (FFR_{CT}). The computation is repeated throughout the cardiac cycle. *Source:* Images have been taken from Taylor et al 2013 [34].

DL in Medicine

Deep Learning at Chest Radiography: Automated Classification of Pulmonary Tuberculosis by Using Convolutional Neural Networks[1]

Paras Lakhani, MD
Baskaran Sundaram, MD

Radiology

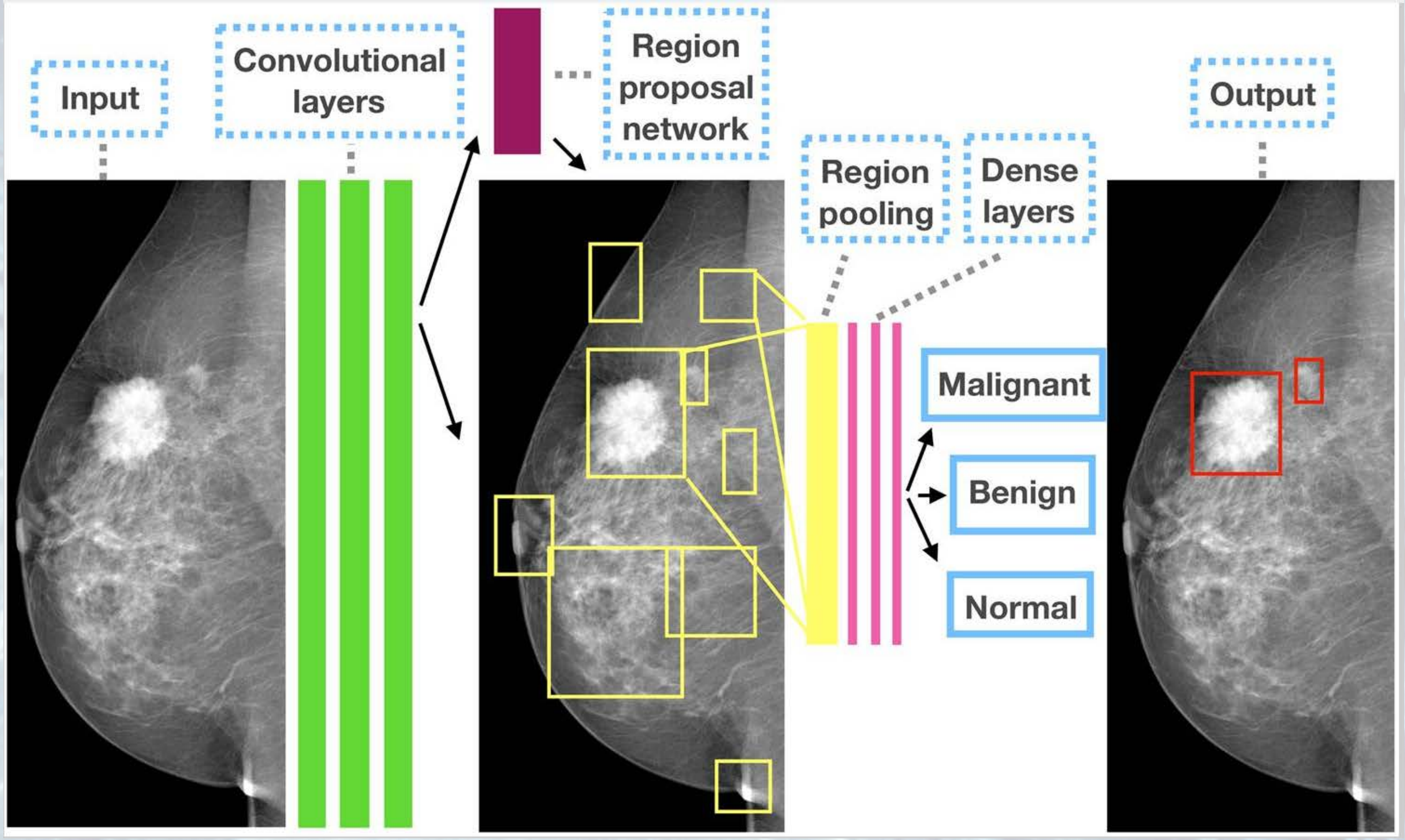


- Similar approaches detected tuberculosis on chest radiographs with 99% accuracy

Lakhani P et al. *Radiology*. 2017 Aug;284(2):574-582.

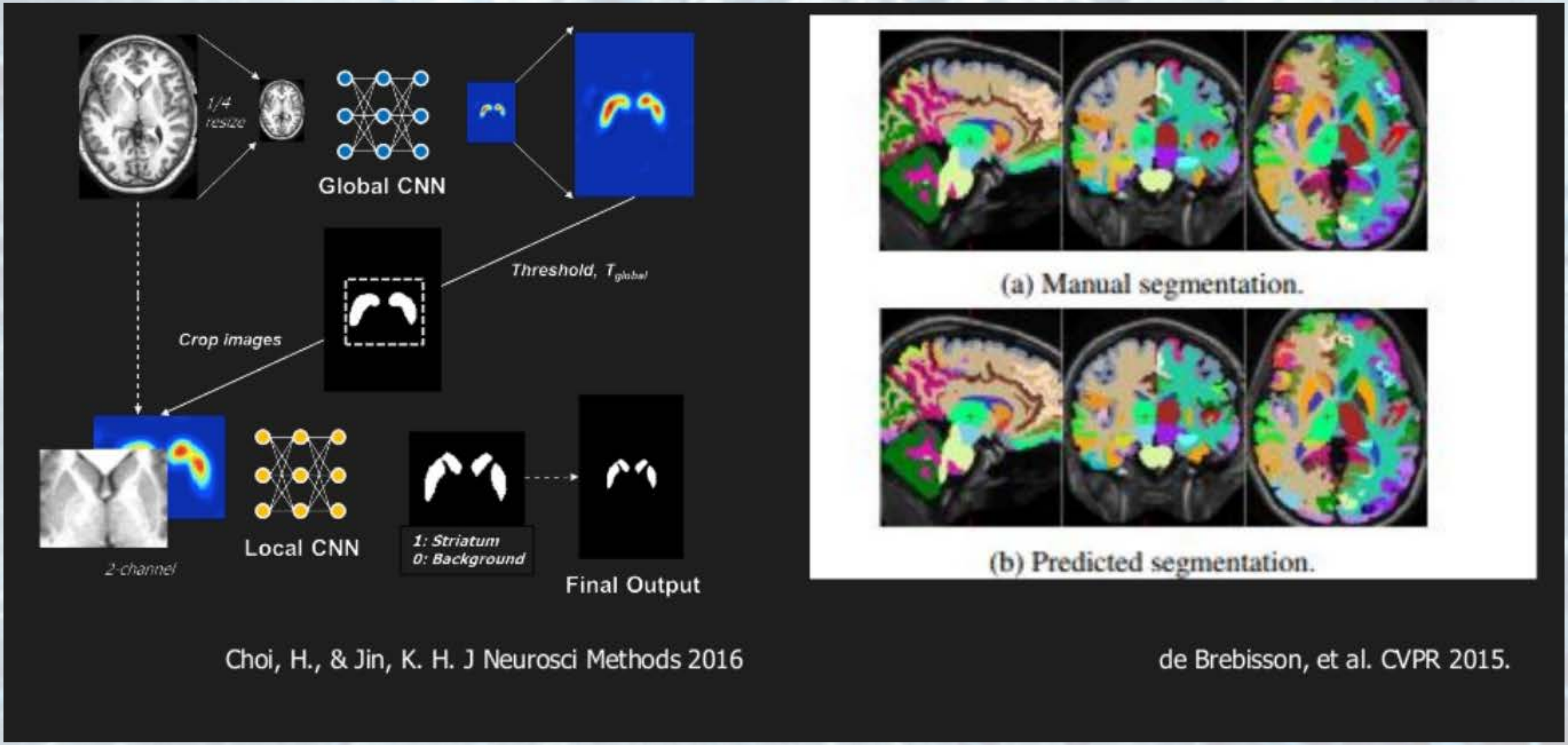
DL in Medicine

MIT Deploys Deep Learning Tool for Analyzing Mammograms



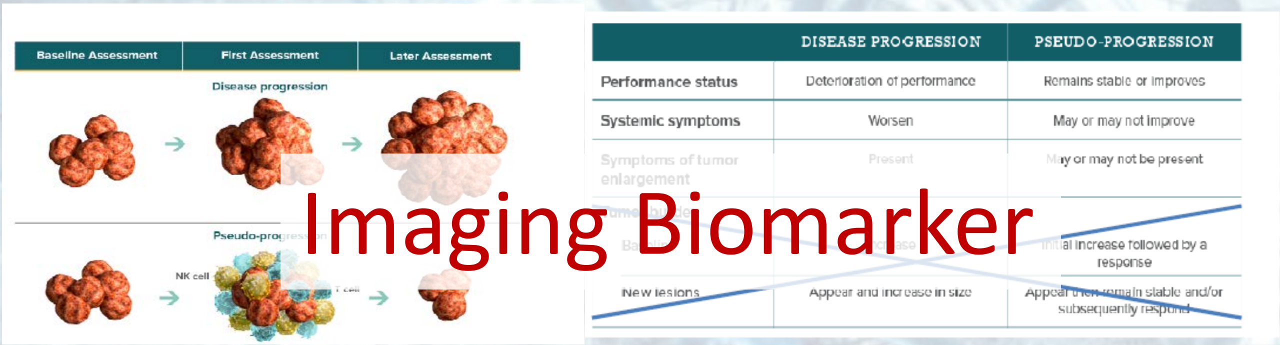
DL in Medicine

Segmentation



Moving toward DL…

Radiomics Immuno-Lung: Correlate CT quantitative parameters to progression of clinical and / or radiological disease



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Objective imaging in Amyloid PET neuroimaging: Automatic quantitative anaysis of PET amyloid images

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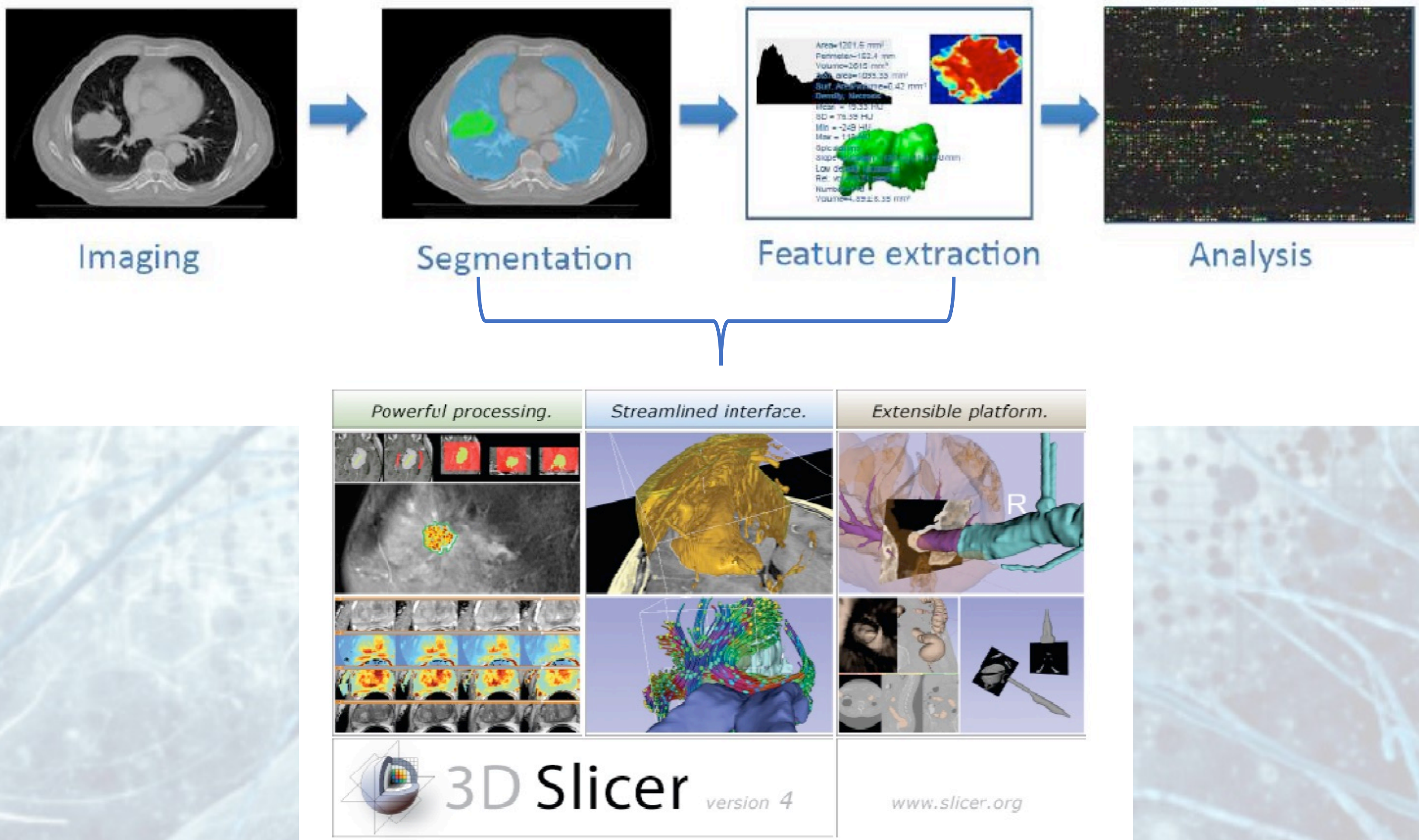
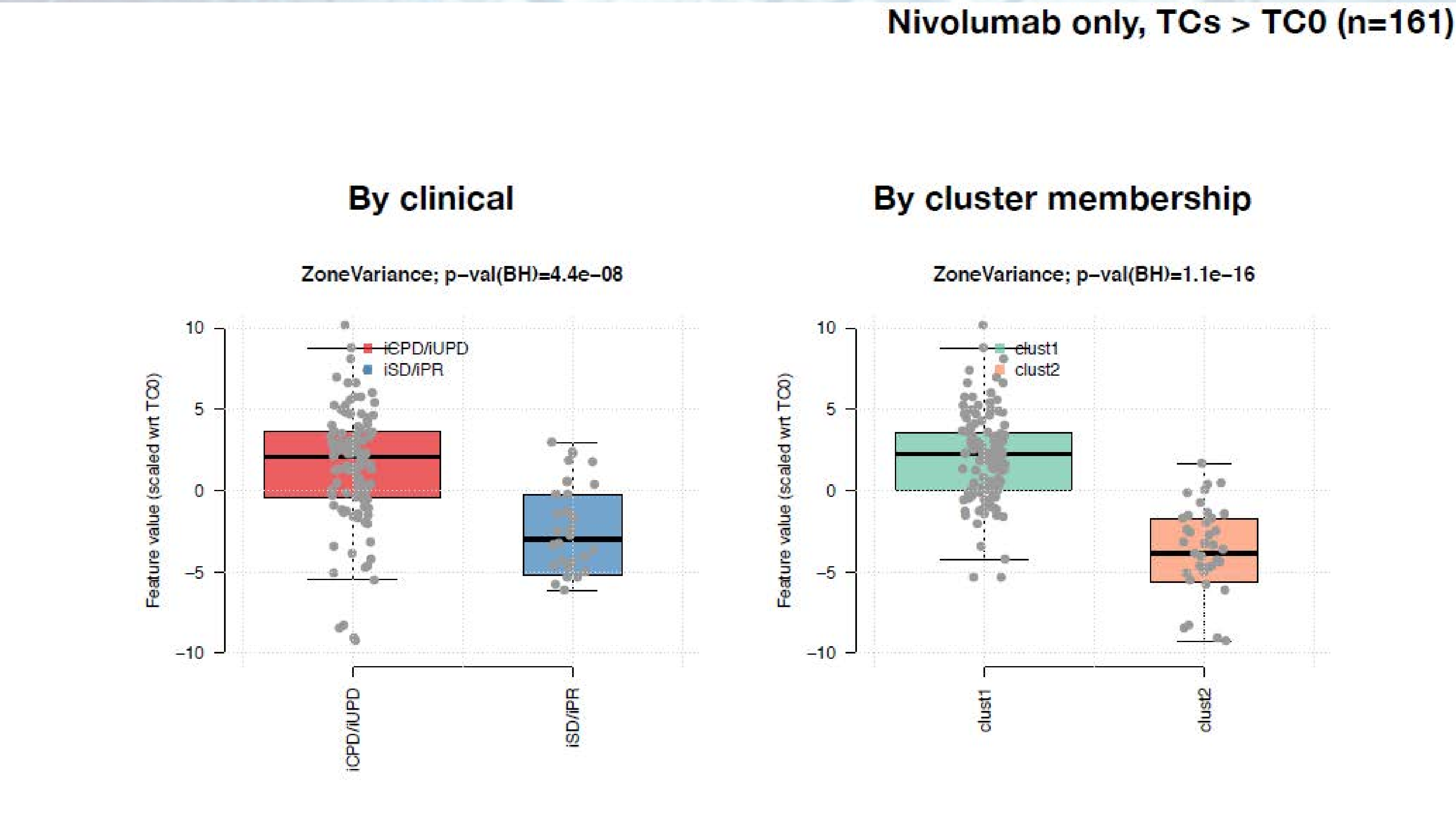
Radiomics Immuno-Lung: Correlate CT quantitative parameters to progression of clinical and / or radiological disease



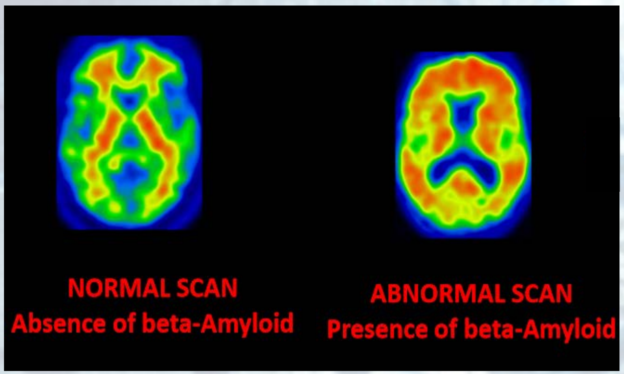
Radiomics Immuno-Lung: Correlate CT quantitative parameters to progression of clinical and / or radiological disease

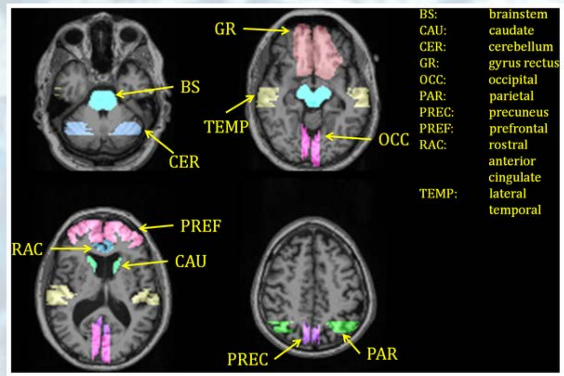


Objective imaging in Amyloid PET neuroimaging: Automatic quantitative anaysis of PET amyloid images

Segmentation

From Fusion and manual contouring





To AutoSegmentation…

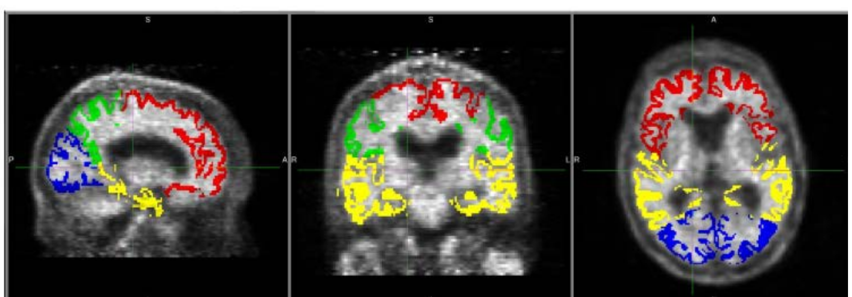


Figure 3.3: Example of image processing outcome in sagittal, coronal and transversal views. The origina PET data is overlaid with the masks for the four lobes. These masks are obtained by applying atlas base masks on the grey-matter-only PET. Frontal lobe is depicted in red, parietal lobe in green, occipita lobe in blue and temporal lobe in yellow.

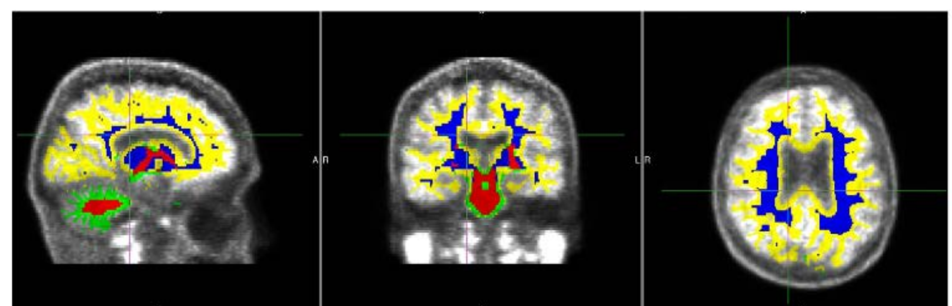


Figure 3.4: Visualization of four white matter based reference regions. All colours summed show the original whole brain white matter region, eroded white matter is represented by red and blue areas together. The white matter region without cerebellum is composed of yellow and blue area and blue alone depicts the smallest option which is eroded and cerebellum stripped of.

Objective imaging in Amyloid PET neuroimaging: Automatic quantitative anaysis of PET amyloid images

Imaging Bi

From One Paramete   mage features

....to

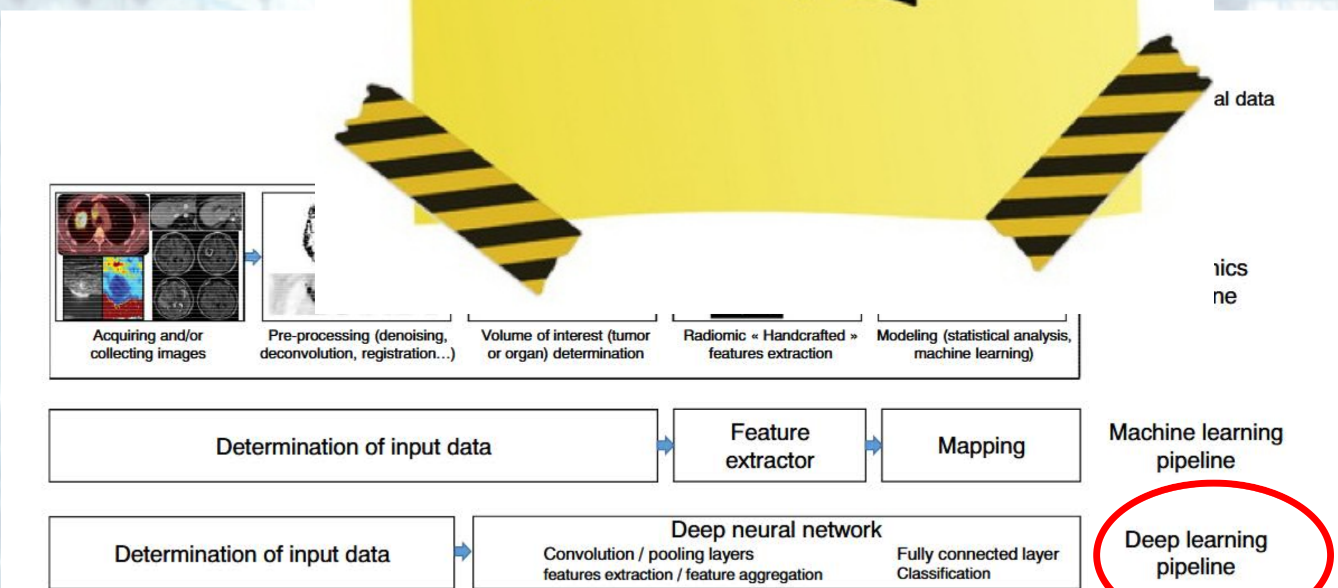


Fig. 1 The radiomics pipeline, in comparison with the usual machine learning workflow, and the deep learning workflow

Visvikis, D., Cheze Le Rest, C., Jaouen, V., & Hatt, M. (2019). *Artificial intelligence, machine (deep) learning and radio(geno)mics: definitions and nuclear medicine imaging applications.* *European Journal of Nuclear Medicine and Molecular Imaging.*

DL in Nuclear Medicine…coming out

Full-Dose PET Image Estimation from Low-Dose PET Image Using Deep Learning: a Pilot Study

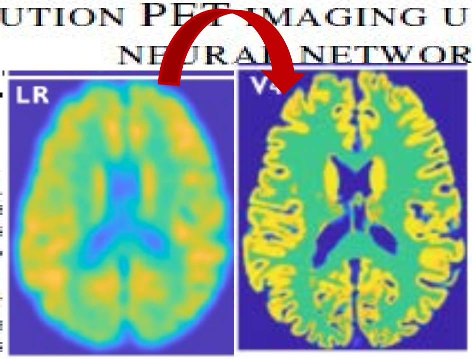
Sydney Kaplan[1,2] · Yang-Ming Zhu[1,3]

Abstract
Positron emission tomography (PET) imaging is an effective tool used in determining disease stage and lesion malignancy; however, radiation exposure to patients and technicians during PET scans continues to draw concern. One way to minimize radiation exposure is to reduce the dose of radioactive tracer administered in order to obtain the scan. Yet, low-dose images are inherently noisy and have poor image quality making them difficult to read. This paper proposes the use of a deep learning model that takes specific image features into account in the loss function to denoise low-dose PET image slices and estimate their full-dose image quality equivalent. Testing on low-dose image slices indicates a significant improvement in image quality that is comparable to the ground truth full-dose image slices. Additionally, this approach can lower the cost of conducting a PET scan since less radioactive material is required in the scan, which may promote the usage of PET scans for medical diagnosis.

Keywords Deep learning · Denoising · Image estimation · Low-dose · PET

1/5 of Dose Administration

Super-resolution PET imaging using convolutional neural networks



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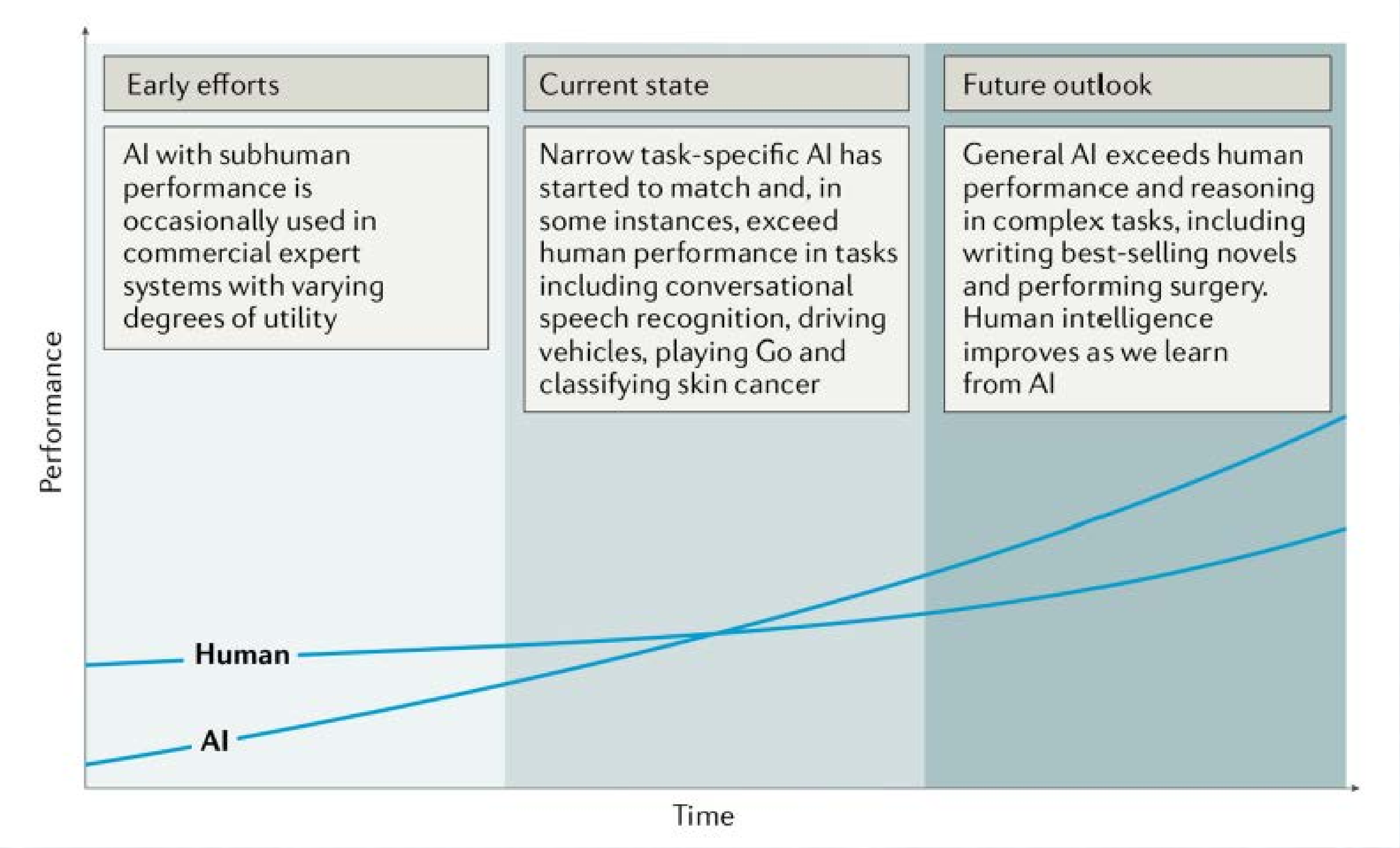
AI in future outlook….



Radiologists and nuclear doctors will be replace by AI?

Probably the ones who will not use it !!