ARTIFICIAL INTELLIGENCE:

Practical?, Productive?, Profitable?
Percipient?, Pansophical?, Prescient?, Perilous?

Dr Lawrence Sim,

Director: Radiology Informatics Support Unit, Health Support Queensland, Queensland Health.

Honorary Fellow: Center for Online Health, University of Queensland.

Cogito, ergo sum
(Rene Descartes)

The robots are coming …
(Kristen Soltis Anderson)

I'm sorry, Dave. I'm afraid I can't do that.
(HAL 9000)

What is Artificial Intelligence?

Accenture (2017): "a constellation of technologies that allow smart machines to extend human capabilities …".

- natural language processing,
- intelligent agents,
- Chatbots,
- voice recognition
- computer vision,
- machine learning,
- expert systems,
- and autonomous cars.

McKinsey (2017): focused on 5 AI technology systems:

- robotics and autonomous vehicles,
- computer vision,
- language
- virtual agents,
- and machine learning,

McKinsey Global Institute, June 2017, Artificial Intelligence: The Next Digital Frontier? McKinsey&Company,

Accenture (2017), Why is Artificial Intelligence Important?
https://www.accenture.com/t20170803T052433Z__w__/au-en/_acnmedia/PDF-54/Accenture-Artificial-Intelligence-AI-Overview.pdf#zoom=50

ARTIFICIAL INTELLIGENCE (AI)
What are we talking about today?

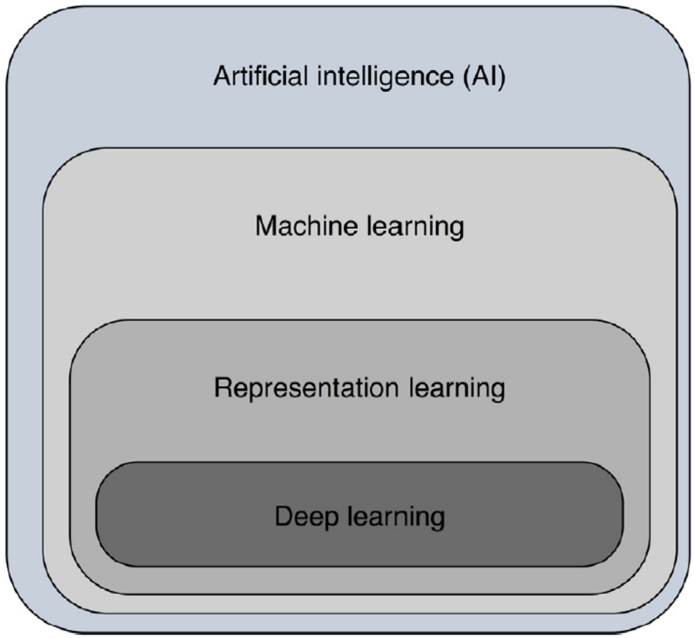


Figure 1. Venn diagram illustrating the hierarchy of artificial intelligence fields defined in the text. Adapted from Goodfellow et al [1] with permission from MIT Press.

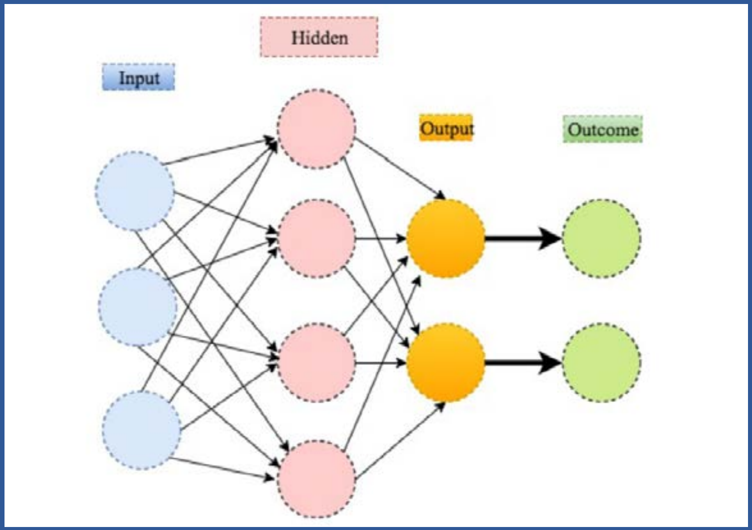
Artificial intelligence:
- A branch of computer science
- Computer algorithms
- Tasks associated with human intelligence
  (e.g. Problem solving, learning, language, …)
- A broad field of endeavor
- Many techniques

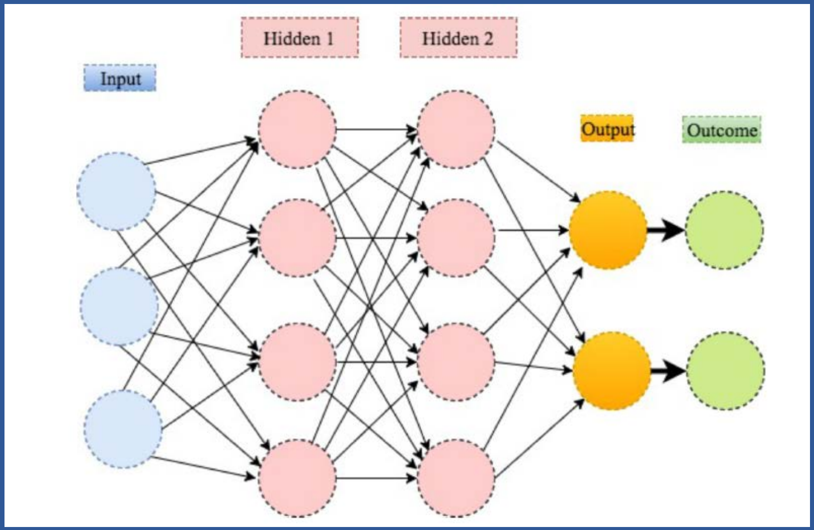
Machine Learning:
- Sub discipline of AI
- Leverages data to provide knowledge

From:
Tang et al (2018), Canadian Association of Radiologists White Paper on Artificial Intelligence in Radiology, Canadian Association of Radiologists Journal, 69; 120-135.

Artificial Neural Networks

Machine learning technologies (algorithms) presently most commonly applied to image analysis





Diagrams from: Jiang F, Jiang Y, Zhi H, et al. (2017), Artificial intelligence in healthcare: past, present and future. Stroke and Vascular Neurology; 0:e000101

Terminology

"Convolutional" Neural Networks: Deep networks that contain convolutional and filtering layers for extracting image detail. Popular in imaging applications – including medical imaging and facial recognition.

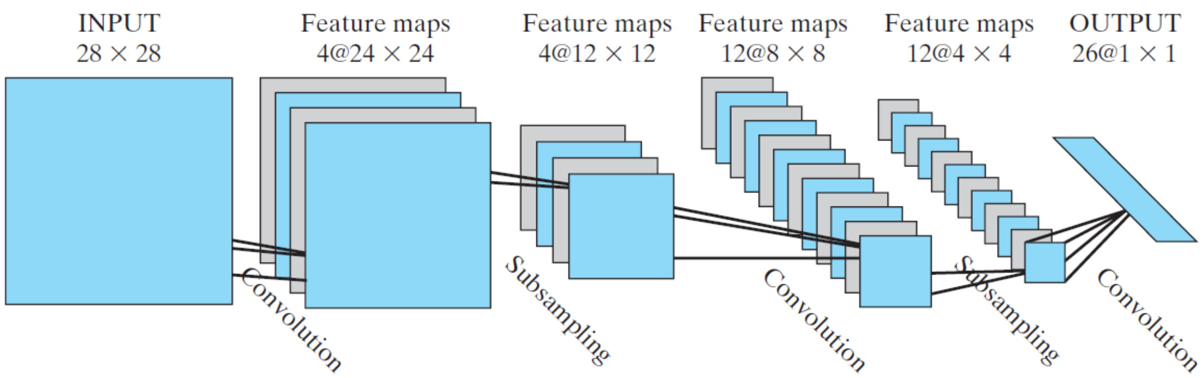


FIGURE 4.23 Convolutional network for image processing such as handwriting recognition. (Reproduced with permission of MIT Press.)

From: Haykin S., (2009), Neural Networks and Learning Machines (Third Edition), Pearson Prentice Hall, New York, (Page 202).

http://dai.fmph.uniba.sk/courses/NN/haykin.neural-networks.3ed.2009.pdf

Terminology

Recurrent Neural Networks: Include feedback and memory nodes. Useful in language apps e.g. remembering for context and predicting next word.

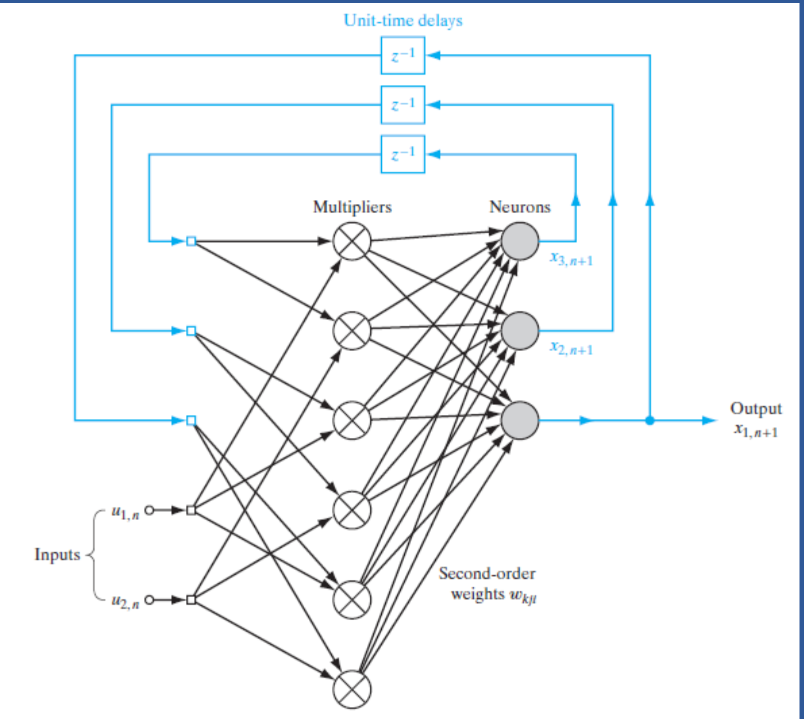


FIGURE 15.5 Second-order recurrent network; bias connections to the neurons are omitted

From: Haykin S., (2009), Neural Networks and Learning Machines (Third Edition), Pearson Prentice Hall, New York, (Page 796).

http://dai.fmph.uniba.sk/courses/NN/haykin.neural-networks.3ed.2009.pdf

Scientific Literature

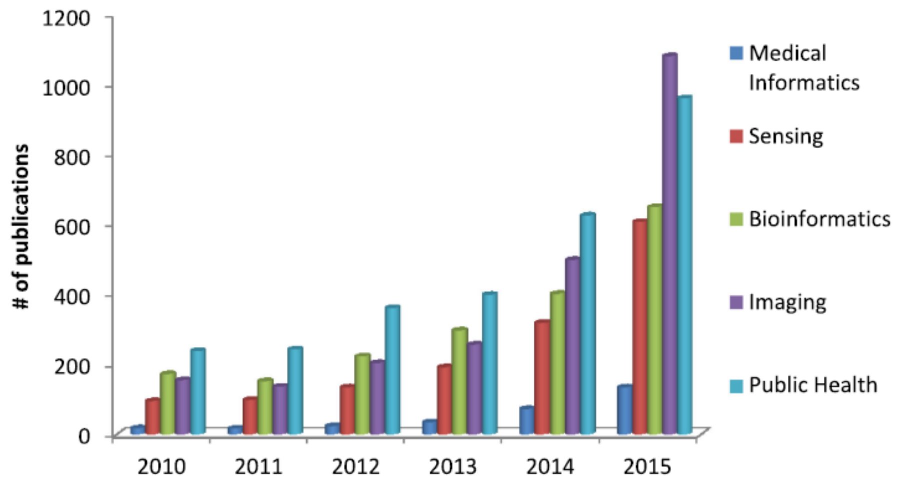


Fig. 1. Distribution of published papers that use deep learning in subareas of health informatics. Publication statistics are obtained from Google Scholar; the search phrase is defined as the subfield name with the exact phrase *deep learning* and at least one of *medical* or *health* appearing, e.g., “public health” “deep learning” medical OR health.

Ravi D., Wong C., Deligianni F., Berthelot M., Andreu-Perez J., Lo B., Yang G., (2017), Deep Learning for Health Informatics, IEEE Journal of Biomedical and Health Informatics, Vol. 21, No. 1. https://spiral.imperial.ac.uk/bitstream/10044/1/42964/9/07801947.pdf

A Short History of AI and Neural Networks

- 1943: McCullough and Pitts – Model biological neuron
- 1951: Turing – "The Imitation Game"
- 1956: The Dartmouth Workshop
- 1957: Rosenblatt's Perceptron
- 1969: Minsky & Papert publish "Perceptrons"
  (A rigorous analysis on of the limitations of Perceptrons).

First AI Winter

- 1980: "Expert Systems" re-invigorate AI research
- 1982: Hopfield networks – revival of "connectionism"
- 1986: Hinton "rediscovers" backpropagation

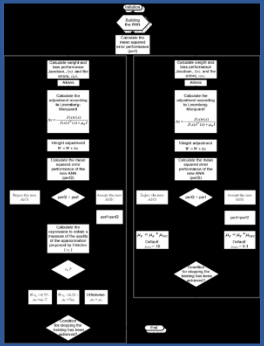
Second AI Winter – Legacy mainframes replaced by Client/Server architectures.

- 1997: IBM Deep Blue defeats Kasparov
- 2011: IBM Watson wins Jeopardy
- 2012: Krizhevsky, Sutskever & Hinton win ImageNet LSVRC-2010 contest
- 2014: Google acquires DeepMind
- 2016: AlphaGo defeats 18 times world Go champion
- 2017: IBM Watson at M D Anderson
- 2018: Cambridge Analytica Scandal

AI Success Factors

- Data collections
- Rise of the internet
- Availability of Computing power
- Availability of capital
- Digital lifestyle factors
- Improved algorithms
  - Analytics
  - Advances in machine learning approaches

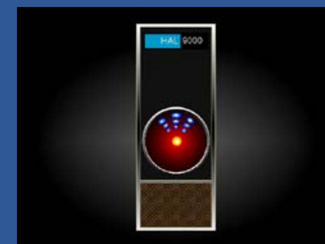




Nothing is as powerful as an idea whose time has come.

– *-Victor Hugo*

Artificial Narrow Intelligence (ANI)
Artificial General Intelligence (AGI)



ANI – “Weak” AI

- Task Specific
- Current state

AGI – “Strong” AI

- Any task to human standard (or beyond)
- Hardware function comparable to human brain
- Aspirational state – Does not exist? Yet?
- Source of much hype

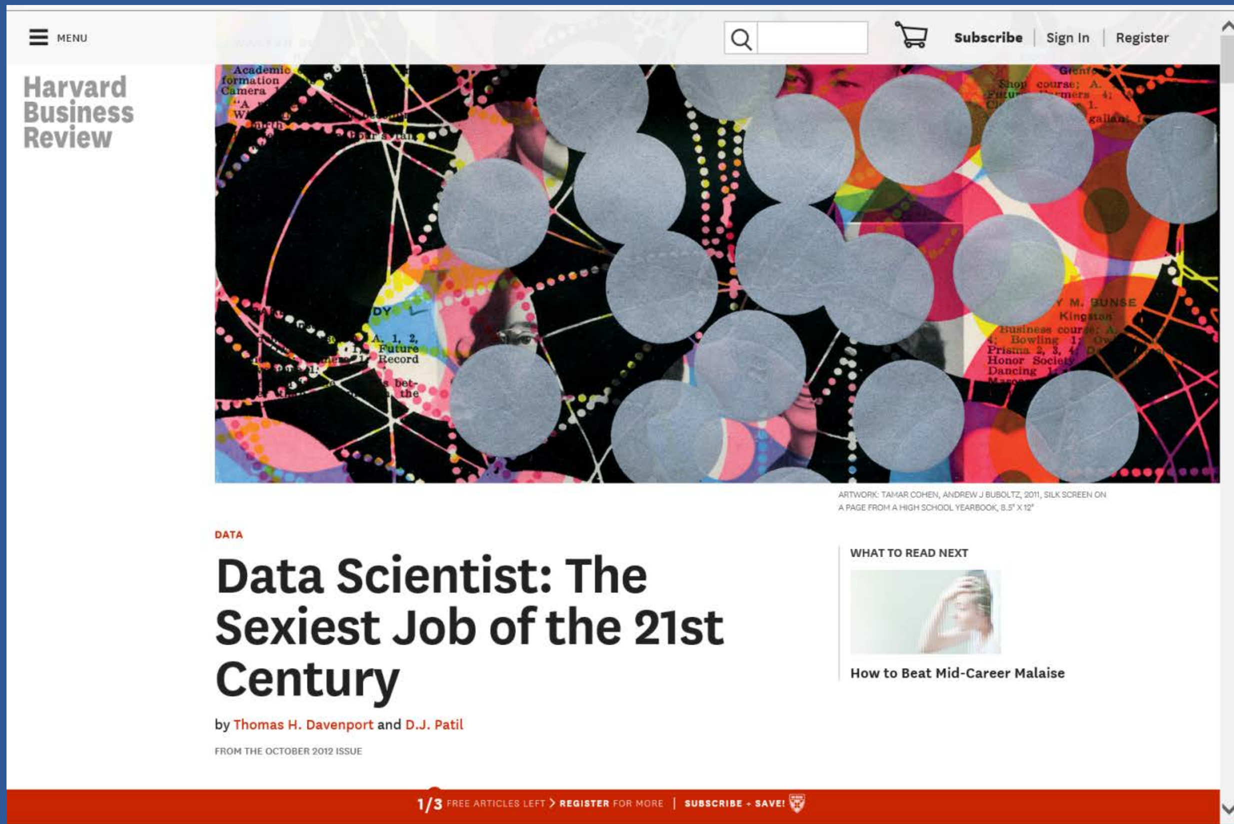
And then … ARTIFICIAL SUPER INTELLIGENCE

Deloitte (2016), Artificial Intelligence Innovation Report, Springwise, London, UK.

Machine Learning

- "Generic" algorithms to analyze data sets without problem specific code.
- The algorithm uses the data to "solve" the problem from patterns and correlations within the data.
- Major categories:
  - Supervised Learning: Grouping and interpreting data based on patterns "learned" from labelled input data.
  - Unsupervised Learning: Developing predictive models based on input data.
  - Reinforcement Learning: The system "learns" through trial and error (i.e. is rewarded for successful decisions).

https://mscdss.ds.unipi.gr/wp-content/uploads/2018/02/Untitled-attachment-00056-2-1.pdf

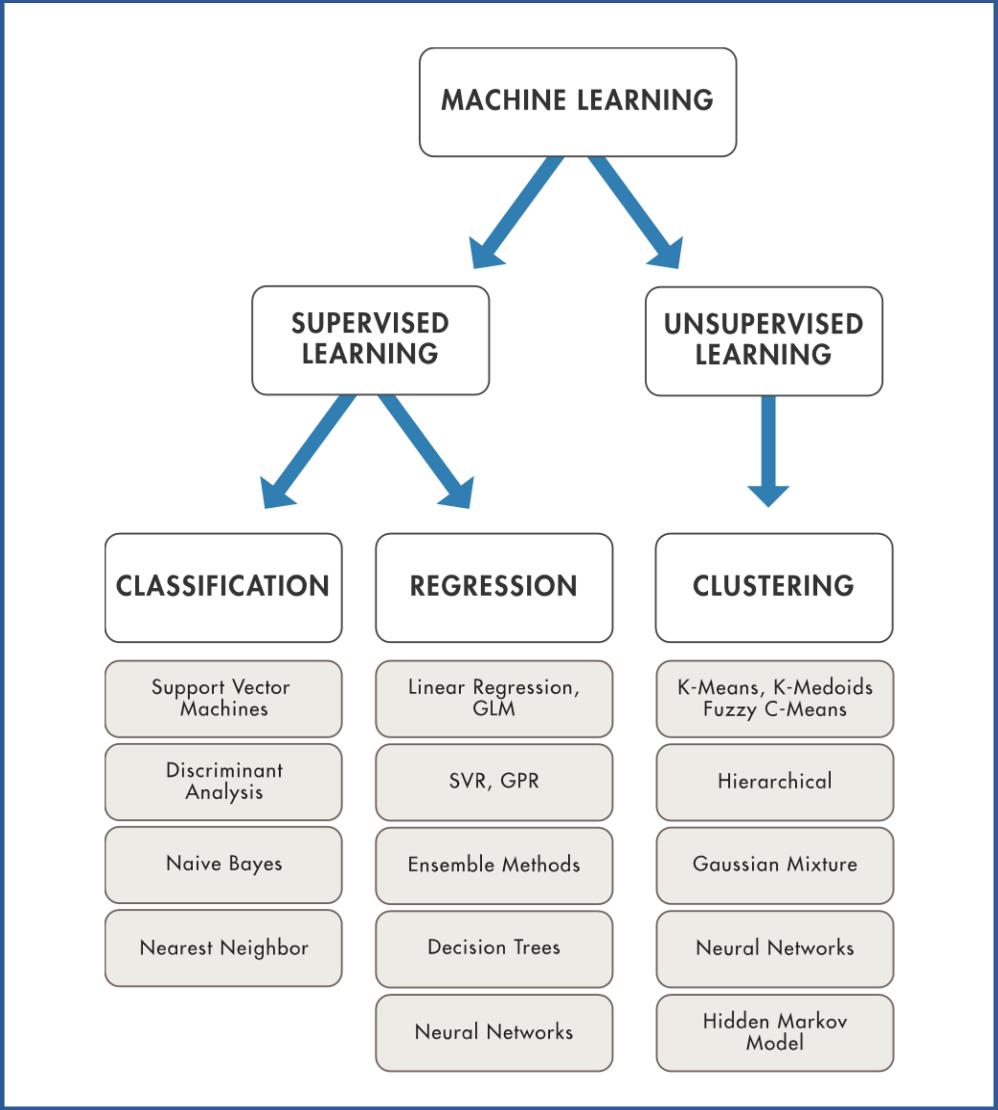


https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century?referral=03758&cm_vc=rr_item_page.top_right

The Artificial Intelligence Skillset

The Applicant must have demonstrable competency in some (or all) of the following areas:

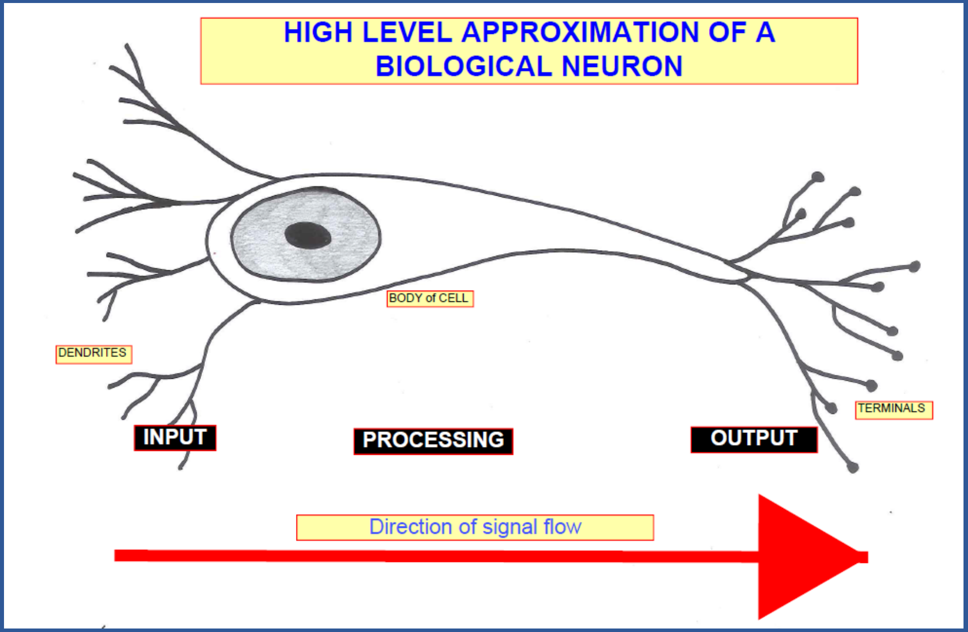
- Mathematics
  - Probability and Statistics (incl. multivariate)
  - Calculus (incl. partial derivatives)
  - Linear Algebra/ Vector Algebra (Vector Spaces, Set Theory, Matrices …)
  - Correlation, Regression, Optimization, Error/Loss/Cost Functions, ….
- Symbolic Knowledge Representation
- Algorithms (e.g. Regression, Principal Components Analysis, Back Propagation, ….)
- Data Science (e.g. Databases, Processing, Manipulation, Representation)
- Computer Science (e.g. OSs, Hardware (e.g. Cloud, Scaleability, Custom Chips ….)
- Programming (Python, R, Java, Cuda(?), C++ ….)
- Online Tools (e.g. Tensorflow, Caffe, MS Cognitive Toolkit/CNTK, Keras, Torch, …)
- Digital Image Processing (e.g. Convolution, Filtering, …)
- Engineering (e.g. Robotic Controls, Advanced Signal Processing, ….)



https://www.mathworks.com/discovery/machine-learning.html

Artificial Neural Networks

- Based on biological neuron structure

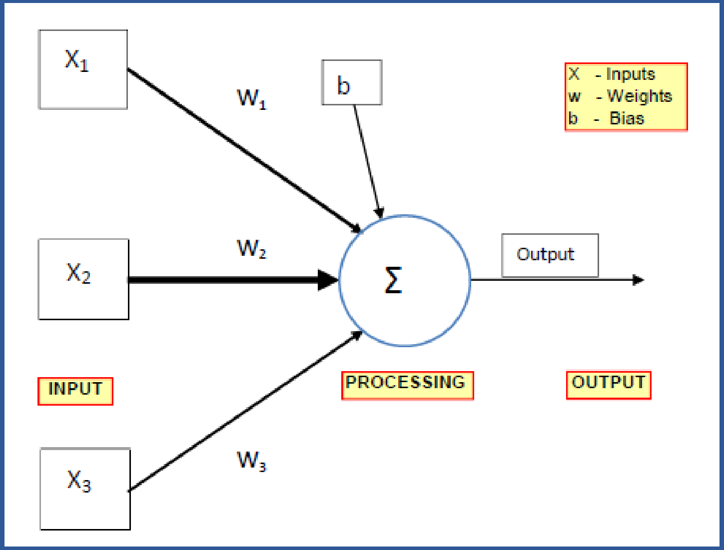


https://www.inf.ed.ac.uk/teaching/courses/nlu/assets/reading/Gurney_et_al.pdf

http://www.dkriesel.com/_media/science/neuronalenetze-en-zeta2-2col-dkrieselcom.pdf

Artificial Neural Networks

- Artificial neuron



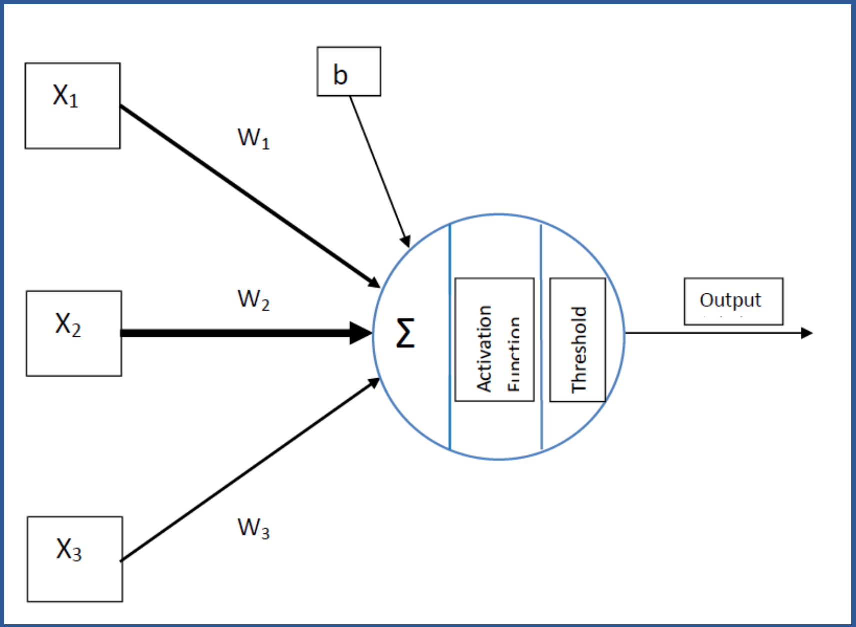
- For this example:

$X_1 = 3.2 \quad W_1 = 0.4$
$X_2 = 1.6 \quad W_2 = 1.0$
$X_3 = 2.8 \quad W_3 = 0.2$
$b = 0.5$

Output $= w_1X_1 + w_2X_2 + w_3X_3 + b$

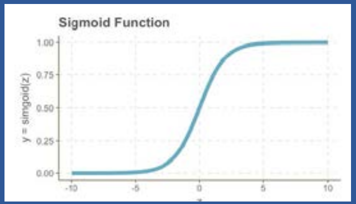
$= 3.94$

Artificial Neural Networks



- Activation Function
  e.g. Sigmoid Function

$$sigmoid(z) = \frac{1}{1+e^{-z}}$$

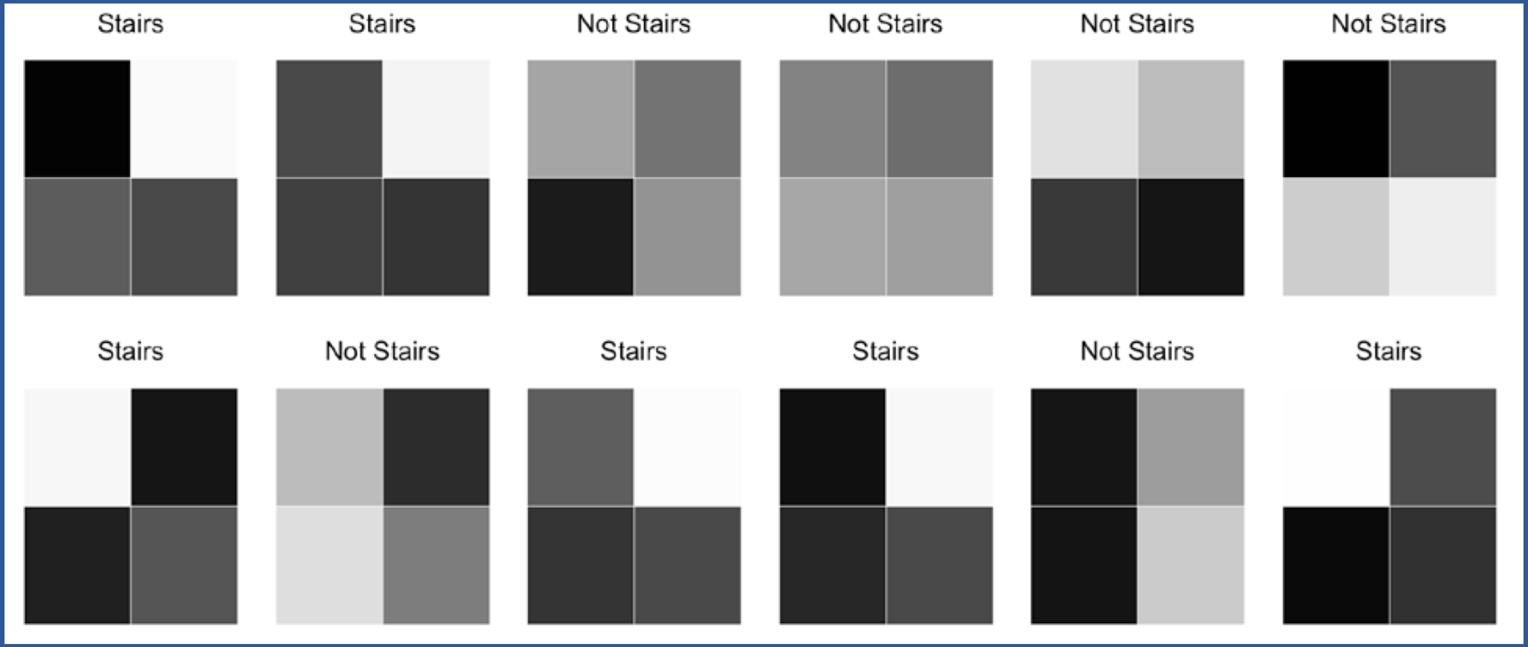


Z = w1X1 + w2X2 + w3X3 + b

Y = sigmoid Z

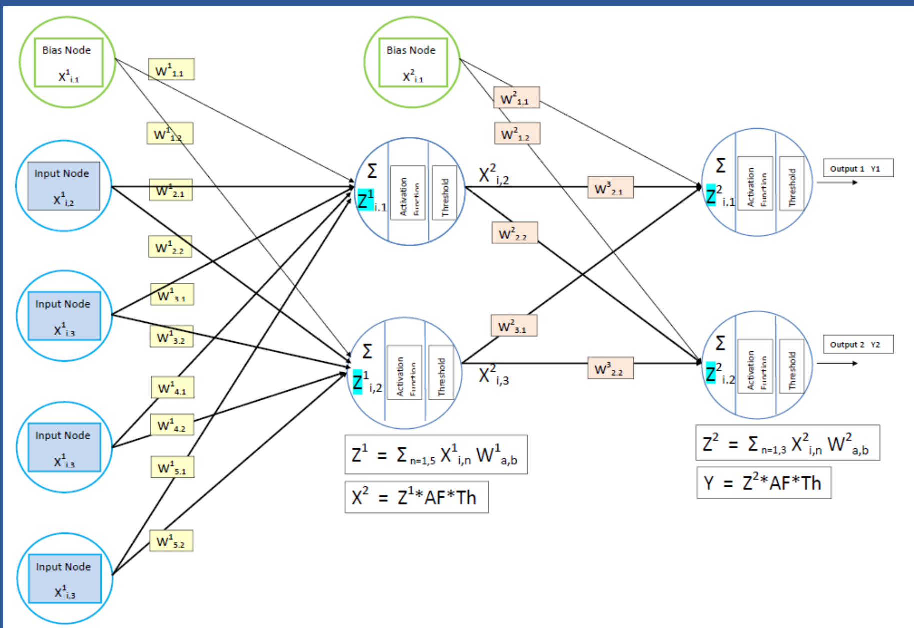
Output = { 1 if Y > 0.5
{ 0 otherwise

What is this good for?



- http://blog.kaggle.com/2017/12/06/introduction-to-neural-networks-2/

From Graph to Numbers



$$\mathbf{Z^1} = \begin{vmatrix} X^1_{1,1} & X^1_{1,2} & X^1_{1,3} & X^1_{1,4} & X^1_{1,5} \\ X^1_{2,1} & X^1_{2,2} & X^1_{2,3} & X^1_{2,4} & X^1_{2,5} \\ X^1_{3,1} & X^1_{3,2} & X^1_{3,3} & X^1_{3,4} & X^1_{3,5} \\ X^1_{4,1} & X^1_{4,2} & X^1_{4,3} & X^1_{4,4} & X^1_{4,5} \\ X^1_{5,1} & X^1_{5,2} & X^1_{5,3} & X^1_{5,4} & X^1_{5,5} \\ - & - & - & - & - \\ X^1_{N,1} & X^1_{N,2} & X^1_{N,3} & X^1_{N,4} & X^1_{N,5} \end{vmatrix} \begin{vmatrix} W^1_{1,1} & W^1_{1,2} \\ W^1_{2,1} & W^1_{2,2} \\ W^1_{3,1} & W^1_{3,2} \\ W^1_{4,1} & W^1_{4,2} \\ W^1_{5,1} & W^1_{5,2} \end{vmatrix} = \begin{vmatrix} Z^1_{1,1} & Z^1_{1,2} \\ Z^1_{2,1} & Z^1_{2,2} \\ Z^1_{3,1} & Z^1_{3,2} \\ Z^1_{4,1} & Z^1_{4,2} \\ Z^1_{5,1} & Z^1_{5,2} \\ - & - \\ Z^1_{N,1} & Z^1_{N,2} \end{vmatrix}$$

$$\hat{\mathbf{Y}} = \begin{vmatrix} X^2_{1,1} & X^2_{1,2} \\ X^2_{2,1} & X^2_{2,2} \\ X^2_{3,1} & X^2_{3,2} \\ X^2_{4,1} & X^2_{4,2} \\ X^2_{5,1} & X^2_{5,2} \\ - & - \\ X^2_{N,1} & X^1_{N,2} \end{vmatrix} \begin{vmatrix} W^2_{1,1} & W^2_{1,2} \\ W^2_{2,1} & W^2_{2,2} \\ W^w_{3,1} & W^w_{3,2} \end{vmatrix} = \begin{vmatrix} \hat{Y}_{1,1} & \hat{Y}_{1,2} \\ \hat{Y}_{2,1} & \hat{Y}_{2,2} \\ \hat{Y}_{3,1} & \hat{Y}_{3,2} \\ \hat{Y}_{4,1} & \hat{Y}_{4,2} \\ \hat{Y}_{5,1} & \hat{Y}_{5,2} \\ - & -- \\ \hat{Y}_{N,1} & \hat{Y}_{N,2} \end{vmatrix}$$

$$\mathbf{Y} = \begin{bmatrix} Y_{1,1} & Y_{1,2} \\ Y_{2,1} & Y_{2,2} \\ Y_{3,1} & Y_{3,2} \\ Y_{4,1} & Y_{4,2} \\ Y_{5,1} & Y_{5,2} \\ - & -- \\ Y_{N,1} & Y_{N,2} \end{bmatrix}$$

To optimize the weights, form a loss function from the known training estimates and the estimates found by the first forward pass through the network.
e.g. Using Cross Entropy as the loss function:

$$CE_i = CE(\hat{Y}_i, Y_i) = -\Sigma_{c=1,C}\, y_{ic} \, Log(\hat{y}_{ic})$$

The task then is to find the minimum value of CE with respect to all of the values of W

AI in Medical Imaging

- "…. despite all the hype, the technology is real and will have a profound impact on how we practice over the next 10 years."
  Dr Curt Langlotz, Speaking with Health Imaging at SIIM 2018.
  https://www.healthimaging.com/topics/artificial-intelligence/curt-langlotz-siim-2018-ais-impact-will-be-real-and-profound

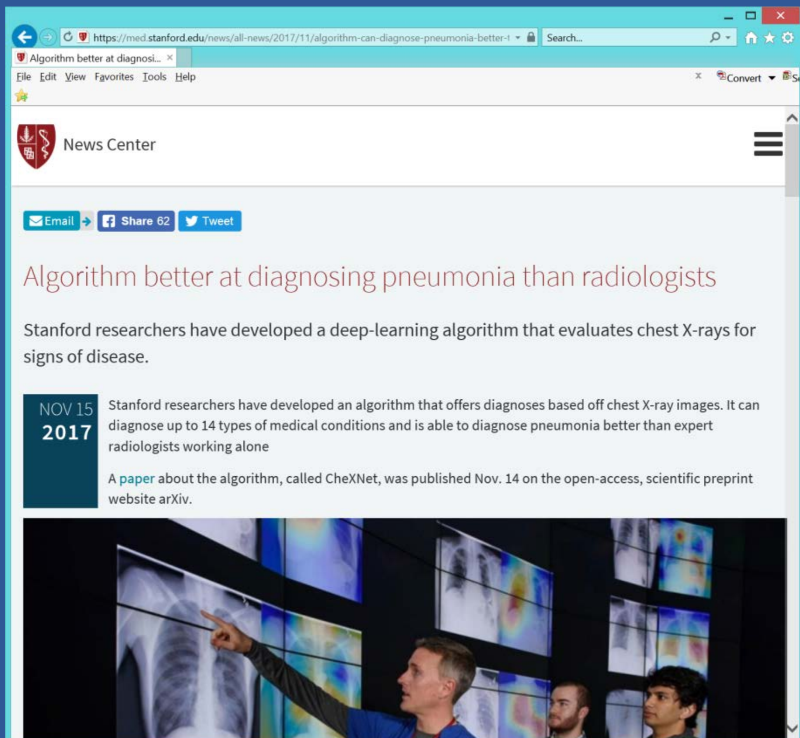
- "Computers will perform much more quantitative imaging and assessment, [but] radiologists are much harder to replace than has been appreciated, and I believe we'll need more radiologists in the future and not less."
  Dr Eliot Siegel, Artificial Intelligence in Medical Imaging: Hype, Reality, and Future Applications, Podcast 21 Feb 2017.
  https://register.gotowebinar.com/register/1708528206599017986

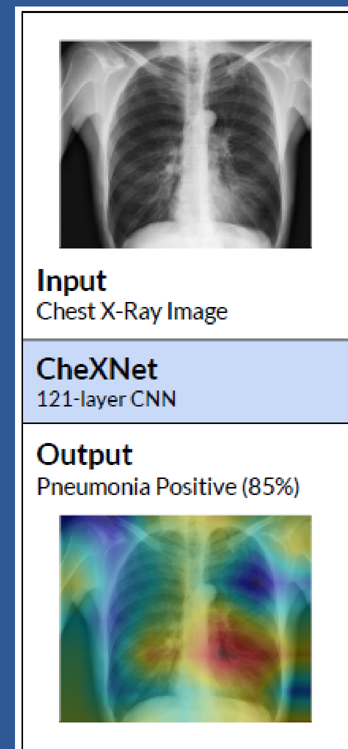
AI in Medical Imaging

- “What we will eventually see in radiology are diagnostic image interpretation systems that have read every textbook and journal article; know all of a patient’s history, records, and laboratory reports; and have memorized millions of imaging studies,”
  “It may help to imagine these systems not as a collection of circuits in a console, but as an army of fellowship-trained radiologists with photographic memories, IQs of 500, and no need for food or sleep.”

  Robert Schier (2018), Artificial Intelligence and the Practice of Radiology: An Alternate View, Journal of the American College of Radiology.

Image Analysis





Rajpurkar P., Irvin J., Zhu K., Yang B., Mehta H., Duan T., Ding D., Bagul A., Langlotz C., Shpanskaya K., Lungren M.P., Ng A.Y., (2017), CheXNet: Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning, arXiv:1711.05225v3

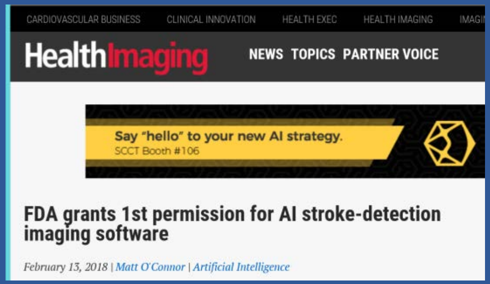
https://arxiv.org/pdf/1711.05225v3.pdf

AI in Medical Imaging

https://www.brighttalk.com/webcast/5565/329774/the-impact-of-artificial-intelligence-in-medical-imaging

- Image Analysis
  - automated image feature detection and analysis
  - "Low hanging fruit"
  - Automation, Accelleration, Augmentation, QA
- Embedded AI
  - Intelligent Modalities: Study context care pathways
  - Self monitoring: Smart asset management
  - Optimized protocoling/personalized acquisition
- Cognitive Computing
  - Ordering: Appropriate ordering of imaging studies
  - Scheduling: Smart booking and patient scheduling
  - Assigning studies: Smart triage, worklist assignment/workflow orchestration
  - Interpretation: Context-aware case preparation and study interpretation
  - Decisions: Data-supported diagnostic inference/ care pathway navigation
  - Reporting: Auto populated quantitative study reports
  - Follow-up: Closed-loop collaboration and communication

Regulatory Approvals



CARDIOVASCULAR BUSINESS CLINICAL INNOVATION HEALTH EXEC HEALTH IMAGING

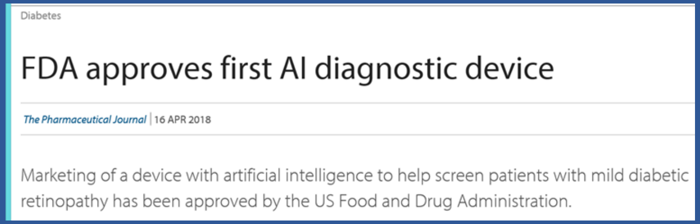
HealthImaging NEWS TOPICS PARTNER VOICE

Say "hello" to your new AI strategy.
SCCT Booth #106

FDA grants 1st permission for AI stroke-detection imaging software

February 13, 2018 | Matt O'Connor | Artificial Intelligence

February 2018:
FDA approved Viz.AI Contact, a system that can enable early detection of a potential stroke by automated analysis of computed tomography results.



Diabetes

FDA approves first AI diagnostic device

The Pharmaceutical Journal | 16 APR 2018

Marketing of a device with artificial intelligence to help screen patients with mild diabetic retinopathy has been approved by the US Food and Drug Administration.

April 2018:
FDA approves IDx-DR , a device that uses AI to help detect an eye disease known as diabetic retinopathy in adults with diabetes.

News > Medscape Medical News > FDA Approvals

FDA Approves AI-Based Software for Wrist Fracture Detection

Rabiya S. Tuma, PhD

DISCLOSURES | May 25, 2018

May 2018:
FDA approved Imagen OsteoDetect, an AI algorithm that uses machine learning techniques to analyze wrist radiographs (X-ray images) to assist clinicians in locating areas of distal radius fracturing.

Challenges

- Black box nature of the algorithms
- Traditional healthcare risk aversion
- Current regulatory model
- Legal liability?
- Inherent bias
- Data
    - Access
    - Quality
    - Privacy

What role does DICOM® have?

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What role does DICOM® have?

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Lugo-Fagundo C., (2018), Deep Learning in Radiology: Now the Real Work Begins (Opinion), J Am Coll Radiol; 15: 364-366.

Choy G. (et al) (2018), Current Applications and Future Impact of Machine Learning in Radiology, Radiology 2018; 288:318–328.

Erickson B.J. (et al) (2018), Deep Learning in Radiology: Does One Size Fit All?, J Am Coll Radiol 2018;15:521-526.

What role does DICOM® have?

STRATEGIC DOCUMENT

Last revised: 2017-03-08

WG-10 (Strategic Advisory)

Challenges and Opportunities (Environment): *incl.*

- Interest in analytics, mineable data and Deep Learning (image headers, SR, MPPS, etc)

  http://dicom.nema.org/Dicom/Geninfo/Strategy.pdf

What role does DICOM® have?

MITA Comments on the Office of the National Coordinator for Health IT’s Draft Trusted Exchange Framework

February 20, 2018

patient diagnosis and treatment across specialties and enterprises. Recent and ongoing industry developments in clinical decision support, powered by computational analytical processes and applications, are acting upon medical imaging data to enable:

- Association of pre-treatment image signatures with known outcomes for prediction of efficacy
- Association of post-treatment image signatures for prognosis of safety (e.g. cardiac toxicity of chemotherapy)
- Integration with other diagnostics for improved stratification to choice of therapy (e.g. Radiogenomics)
- Continual training and validation of supporting AI, machine learning, and NLP algorithms

Capabilities such as these stand to accelerate clinical adoption of innovations, while advancing medical discoveries and innovations from research settings into the clinic. Ongoing support for these advancements on a national scale will require broadband connectivity specification within TEFCA to drive deep learning and informed clinical decision support.

In addition to specification of broadband support, MITA advocates sharing medical image data across the trusted exchange framework in an early stage using industry communication standards. Proven standards based on DICOM for sharing medical images across enterprises are already available, and include but are not limited to:

- DICOMweb
- IHE WIA
- IHE XCA-I
- IHE XDS-I.b (in support of diagnostic imaging results)

Explicit support for broadband connectivity and these imaging standards in concert with those already specified in

Conclusion

- A third AI winter is not approaching. *Social disruption is*!
- Imaging and diagnostics are targets for AI apps.
- Radiologists will not be replaced by machines – just yet.
- Countries with large populations and limited health services may lead front line adoption.
- AI in therapies?
- Data lakes will support precision medicine.
- Regulatory issues will be resolved.
- Healthcare - increasingly dependent upon AI.

End of presentation

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