AI in healthcare

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What is Artificial Intelligence

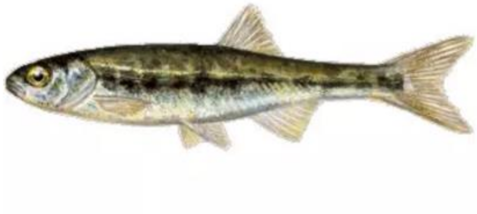
- Definitions
  - “artificial intelligence is intelligence demonstrated by machines”
  - “machines that mimic cognitive functions that humans associate with the human mind, such as learning and problem solving”
- Machine Learning (“ML”), one of the most exciting areas for Development of computational approaches to automatically make sense of data
- Example: Face recognition system
  - How does the brain recognize faces? Do we understand it?
  - Instead of writing a program by hand, we can collect lots of examples that specify the correct output of a given input
  - A machine learning algorithm then takes these examples and produces a program that does the job
  - If we do it right, the program works for a new cases as well as the ones we trained it on.

Machine learning – an example

Machine learning – an example (Cont.)

Feature: Location is Hardangervidda national park

Ørret (Salmo trutta)



Ørekyte (Phoxinus phoxinus)

Røye (Salvelinus alpinus)

Sik (Coregonus lavaretus)

Feature: fishing net used can hold fishes less than 20 cm and less than 3 kg
Observation: Around 80% of fishes observed in last hour were of white colour

Ørret (Salmo trutta)
Brown Trout | Forelle

Size: 18–80 cm.
Weight: 1–3 kg + 15 kg

Ørekyte (Phoxinus phoxinus)
Minnow | Elritze

Size: 8–12 cm
Weight: 100 gram - 2,5 kg

Røye (Salvelinus alpinus)
Char | Saibling

Size: 15-75 cm.
Weight: 100 gram -3 kg

Sik (Coregonus lavaretus)
Whitefish | Felchen

Size: 15–25cm.
Weight: 300-400 gram

What do machine learning algorithms do?

- Search through data to look for patterns
- Patterns in form of trends, associations, classes etc.
- Express these patterns as mathematical structures such as probability equations or polynomial equations

When is machine learning useful ?

- Cannot express our knowledge about patterns as a program. For e.g. Character recognition or natural language processing or image processing
- Do not have an algorithm to identify a pattern of interest. For e.g. In spam mail detection
- Too complex and dynamic. For e.g. Weather forecasting
- Too many permutations and combinations possible. For e.g. Genetic code mapping
- No prior experience or knowledge. For e.g. Mars rover

Data representation in mathematical space

- A data set representing the real world, is a collection attributes that define an entity
- Each entity is represented as one record / line in the data set
- Each attribute becomes a dimension
- Each record becomes a point in the space

http://mercury.webster.edu/aleshunas/Data%20Sets/Supplemental%20Excel%20Data%20Sets.htm

PG Concentration	Diastolic BP	Tri Fold Thick	Serum Ins	BMI	DP Function	Age	Diabetes
148	72	35	0	33.6	0.627	50	Sick
85	66	29	0	26.6	0.351	31	Healthy
183	64	0	0	23.3	0.672	32	Sick
89	66	23	94	28.1	0.167	21	Healthy
137	40	35	168	43.1	2.288	33	Sick
116	74	0	0	25.6	0.201	30	Healthy
78	50	32	88	31	0.248	26	Sick
115	0	0	0	35.3	0.134	29	Healthy
197	70	45	543	30.5	0.158	53	Sick
125	96	0	0	0	0.232	54	Sick
110	92	0	0	37.6	0.191	30	Healthy
168	74	0	0	38	0.537	34	Sick
139	80	0	0	27.1	1.441	57	Healthy
189	60	23	846	30.1	0.398	59	Sick

Data representation in mathematical space (Cont ...)

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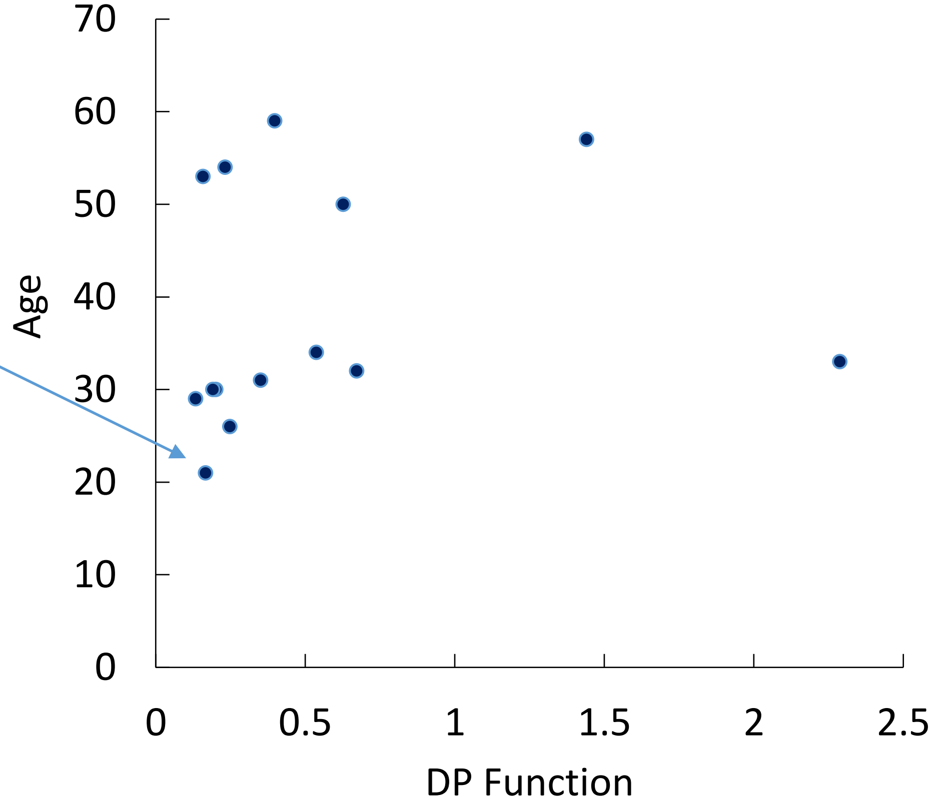
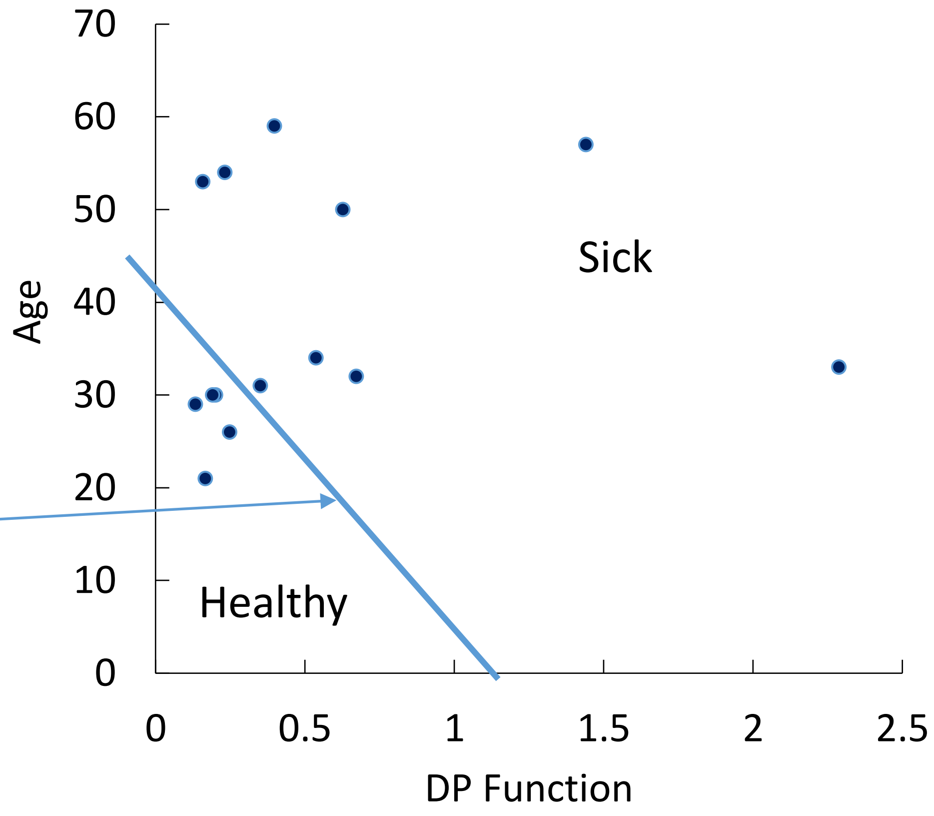


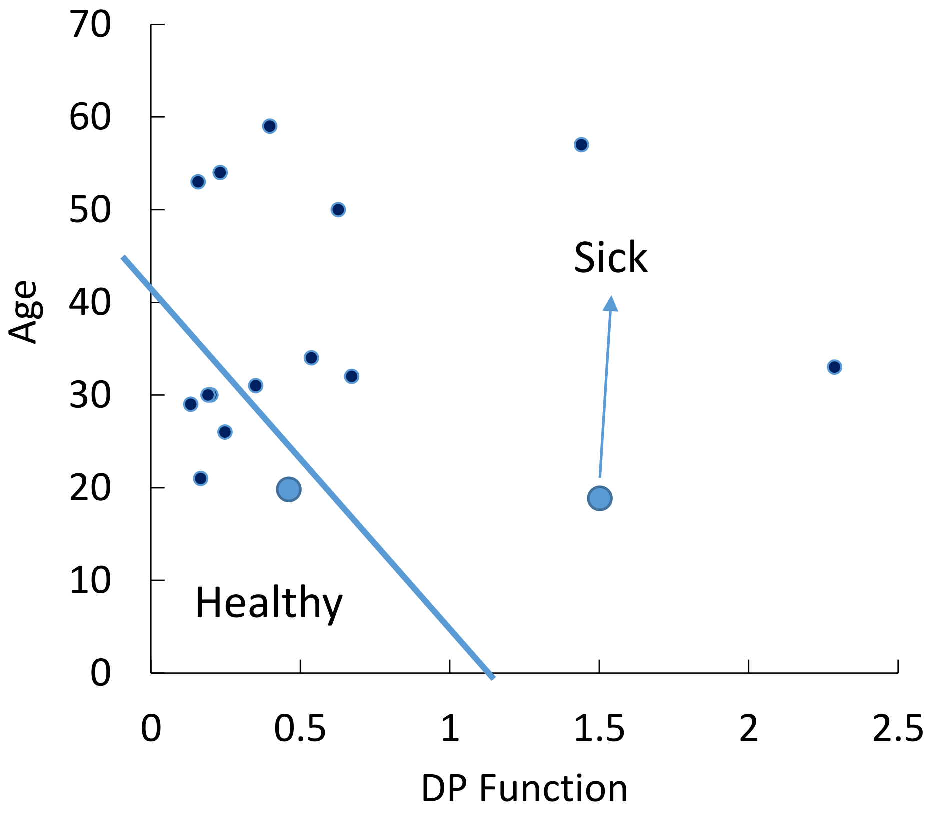
Data representation in mathematical space (Cont …)

- Position of a point in space is defined with respect to the origin
- The position is decided by the values of the attributes for a point
- A model represents the real world process that generated the different set of data points
- The model could be a simple plane, complex plane, hyper plane
- The learning algorithm selects that hypothesis which minimizes errors in the data



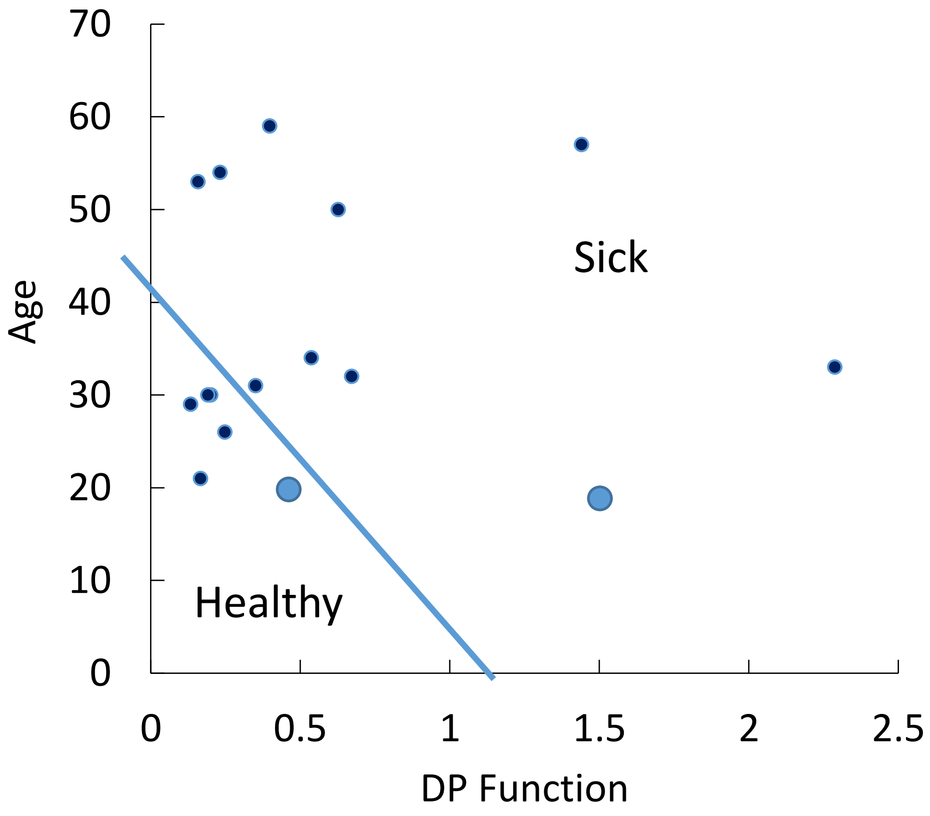
Data representation in mathematical space (Cont ...)

- In the figure, since the separator is a line, the model will be the equation of the line (y = mx + c)
- x , y represent the two dimensions i.e. Age and DP Function
- A new data point enters the system
- It's x and y values will be fed into the model to get (healthy or sick)
- The data point will be placed above or below the line

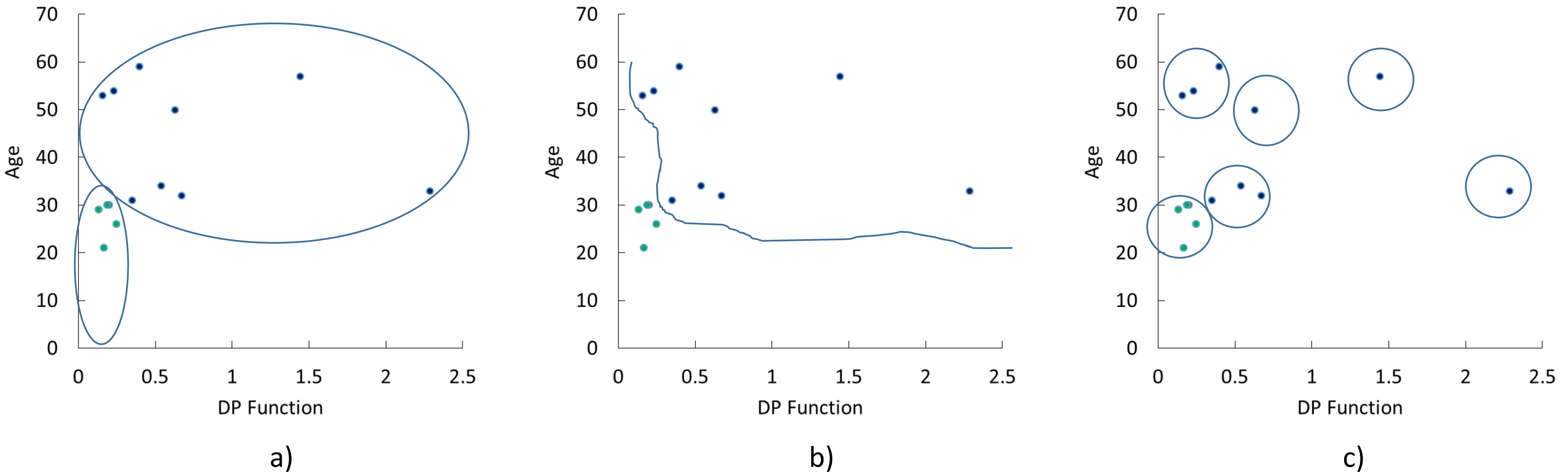


Data representation in mathematical space (Cont …)

- Whether the new data point is correctly placed (above or below the plane) i.e. correctly classified as sick or healthy hear will be known only after direct observation
- Only direct test on the object of interest will tell whether the classification is correct or not
- If majority of new data points are correctly classified, the model is good else not



Alternative solutions



AI in healthcare

- Artificial intelligence (AI) is expected to significantly influence medical practice, however only a handful of practical examples for its medical use are seen, hype around the topic is unprecedented

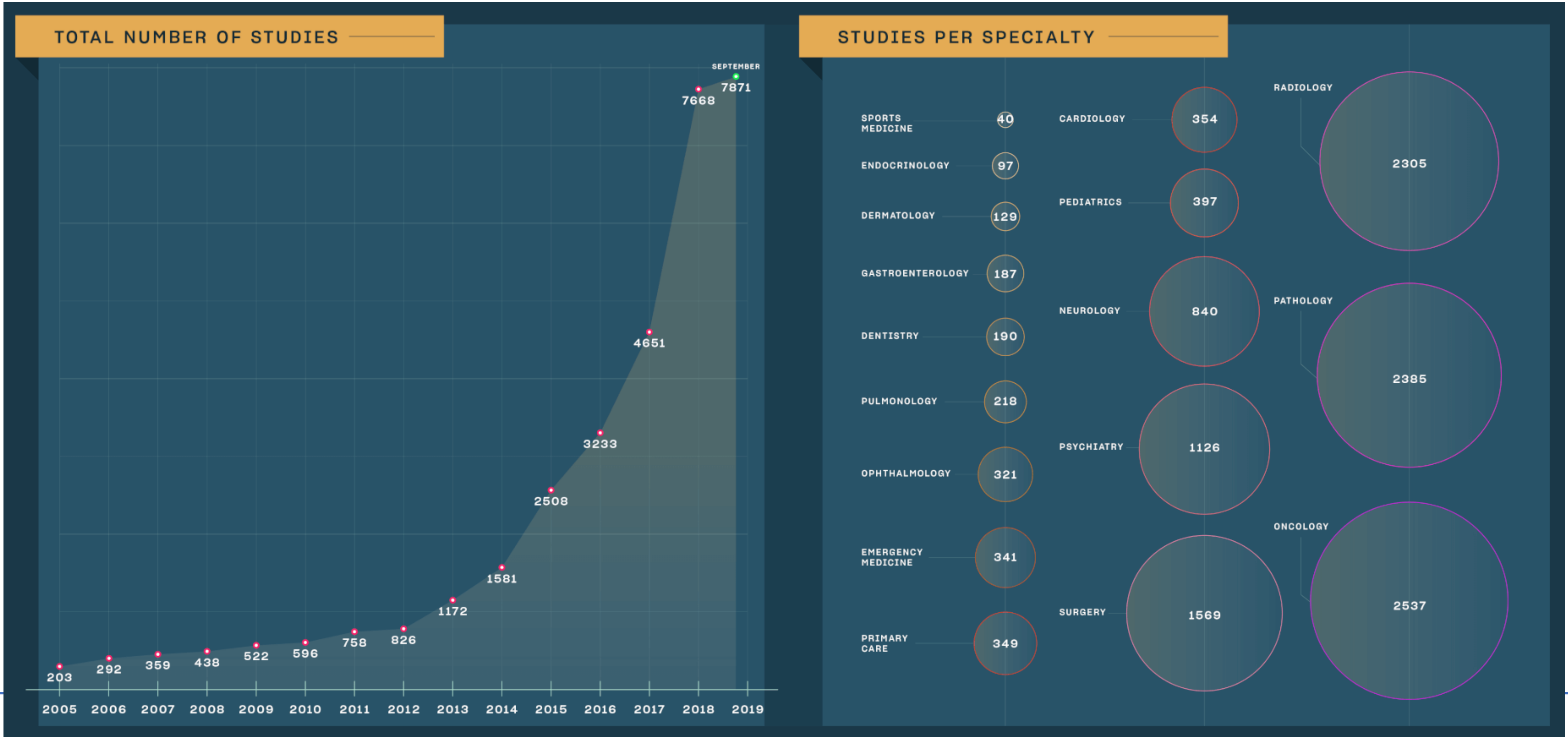
- It has potentials in medicine, drug design and healthcare, yet, the proof and evidence are yet to be convincing enough for the general public and the medical community to adopt the technology

- For AI to succeed, it is critical that physicians understand the basics of the technology so they can see beyond the hype, evaluate AI based studies and clinical validation; as well as acknowledge the limitations and opportunities AI offers.

Innovations in Medical and Biological Engineering

- 1950s and earlier
  - Artificial Kidney
  - X ray
  - Electrocardiogram
  - Cardiac Pacemaker
  - Cardiopulmonary bypass
  - Antibiotic Production technology
  - Defibrillator
- 1970s
  - Computer assisted tomography
  - Artificial hip and knee replacements
  - Balloon catheter
  - Endoscopy
  - Biological plant food engineering
- 1960s
  - Heart valve replacement
  - Intraocular lens
  - Ultrasound
  - Vascular grafts
  - Blood analysis and processing
- 1980s
  - Magnetic resonance imaging
  - Laser surgery
  - Vascular grafts
  - Recombinant therapeutics
- Present day
  - Genomic sequencing and microarrays
  - Positron Emission tomography
  - Image guided surgery
  - AI

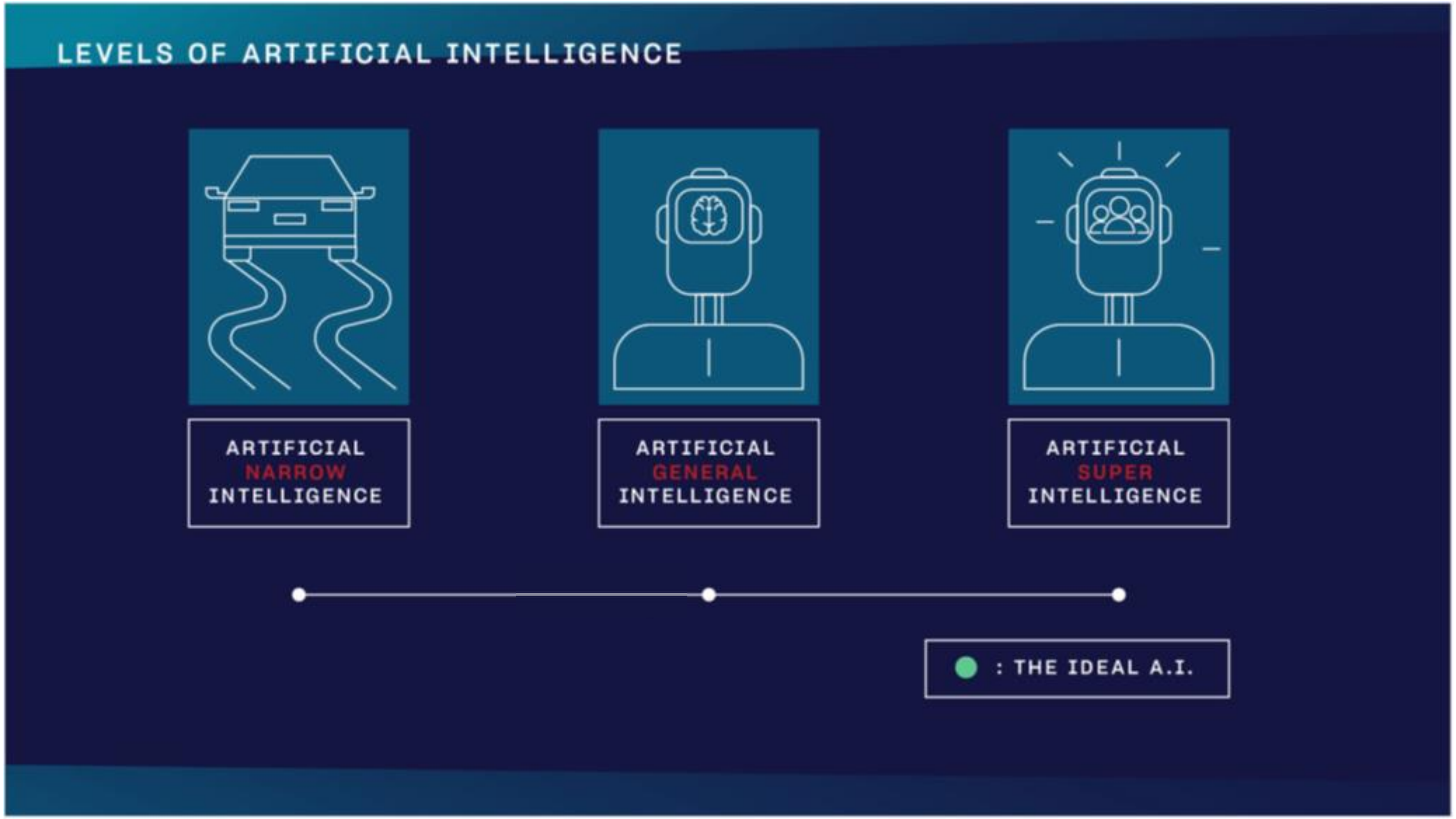
Machine learning and deep learning studies on pubmed.com



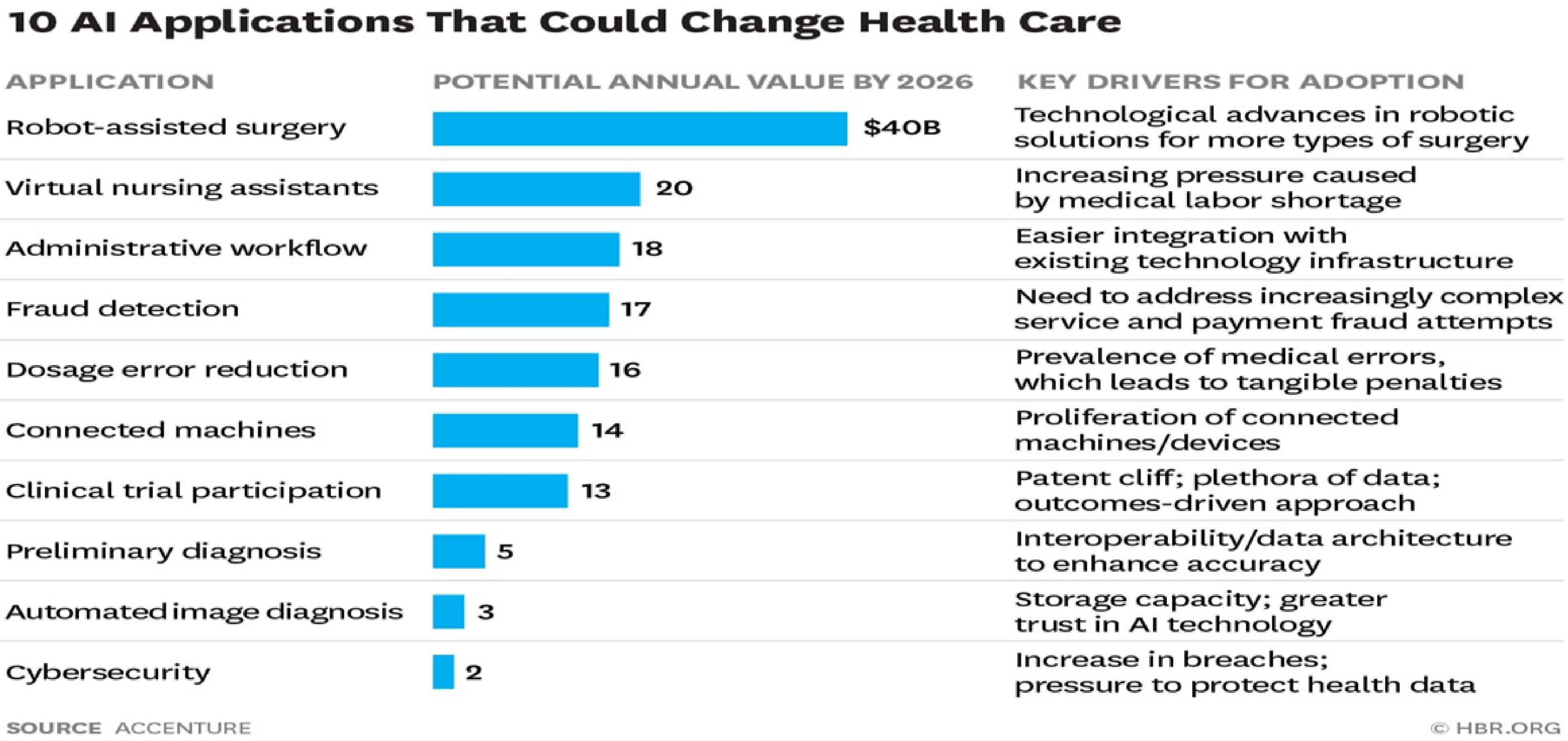
Levels of AI

- According to Nick Bostrom, philosopher at the University of Oxford, three major levels in the development of AI:
  - Artificial Narrow Intelligence (ANI): pattern recognizing abilities in huge data sets, which makes it perfect for solving text, voice, or image-based classification and clustering problems.
  - Artificial General Intelligence (AGI): one day could have a human being’s comprehensive and total cognitive capacity. This is human level AI. It can reason, argue, memorize and solve issues like we do.
  - Artificial Super Intelligence (ASI): theoretically could have humanity’s combined cognitive capacity or even more. Humanity, obviously, would not be able to grasp its knowledge and understand its reasoning. Do we need this?

Definition and levels of AI



Promising AI applications in healthcare



10 AI Applications That Could Change Health Care

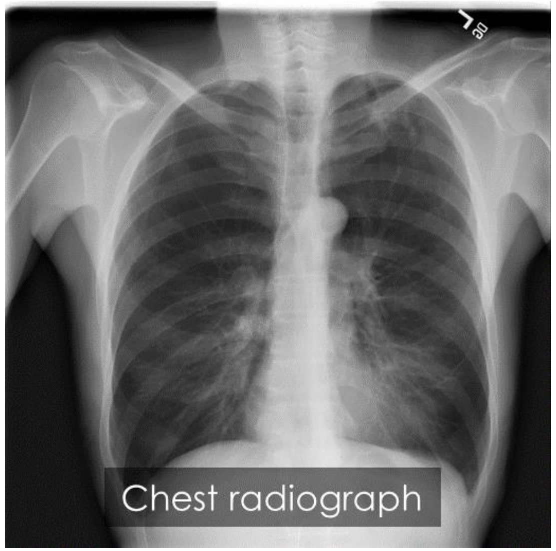
APPLICATION	POTENTIAL ANNUAL VALUE BY 2026	KEY DRIVERS FOR ADOPTION
Robot-assisted surgery	$40B	Technological advances in robotic solutions for more types of surgery
Virtual nursing assistants	20	Increasing pressure caused by medical labor shortage
Administrative workflow	18	Easier integration with existing technology infrastructure
Fraud detection	17	Need to address increasingly complex service and payment fraud attempts
Dosage error reduction	16	Prevalence of medical errors, which leads to tangible penalties
Connected machines	14	Proliferation of connected machines/devices
Clinical trial participation	13	Patent cliff; plethora of data; outcomes-driven approach
Preliminary diagnosis	5	Interoperability/data architecture to enhance accuracy
Automated image diagnosis	3	Storage capacity; greater trust in AI technology
Cybersecurity	2	Increase in breaches; pressure to protect health data

SOURCE ACCENTURE

Few examples of solving complex healthcare problems using AI

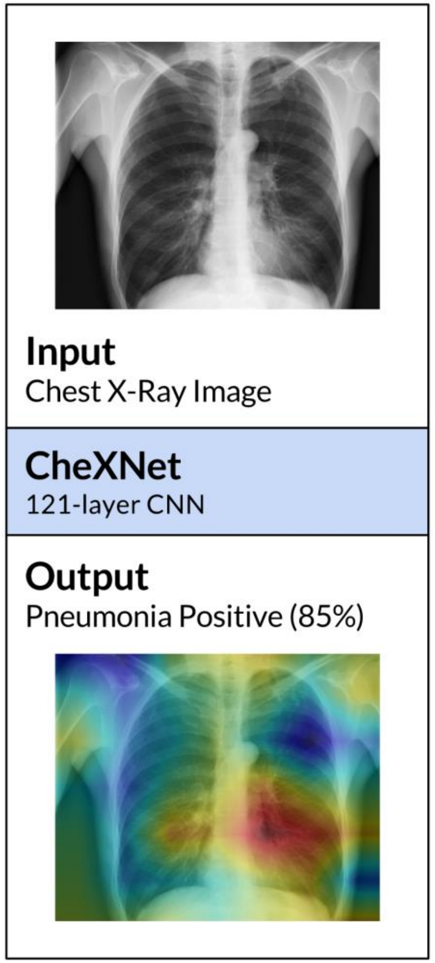
Chest X-ray Image Classification

- Chest radiography (CXR) is a most widely used radiography test. It is typically used as an initial diagnostic assessment tool by radiologists for several thoracic abnormalities such as tuberculosis, pneumonia, nodules, mass, cardiomegaly and many others.
- Interpretation of these radiographs is a tedious job, which is further multiplied by the ratio of number of CXR to that of well-trained radiologists.
- The situation is even worse in resource-poor areas, where radiology services are inadequate.
- Therefore, an automation in this area to help radiologists would be pragmatic particularly to reduce the abnormal missed cases.
- The issue of missed cases is more severe with abnormal conditions like nodules.

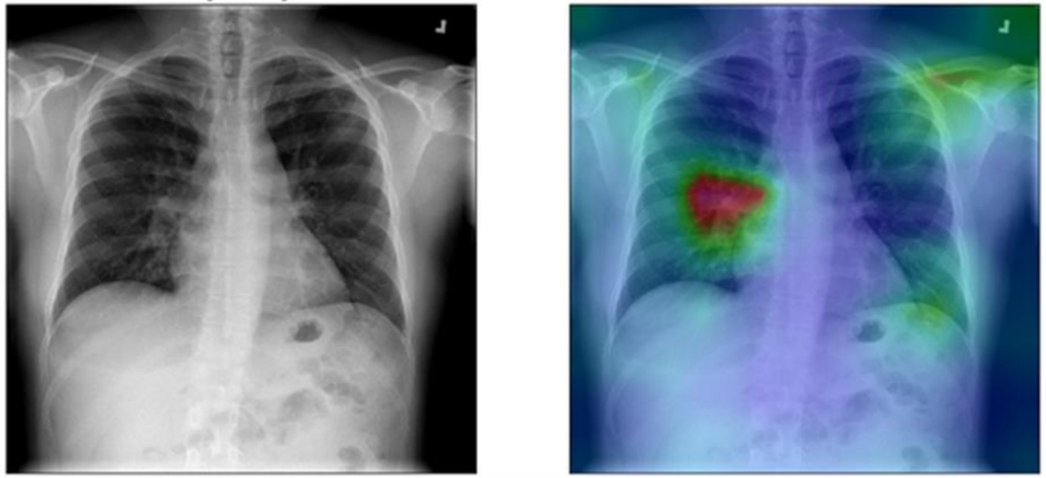


ChexNet - Radiologist-Level Pneumonia Detection on Chest X-Rays with Deep Learning

- CheXNet, is a 121-layer convolutional neural network that inputs a chest X-ray image and outputs the probability of pneumonia along with a heatmap localizing the areas of the image most indicative of pneumonia.
- CheXNet is trained on, ChestX-ray dataset, which contains 112,120 frontal-view chest X-ray images individually labeled with up to 14 different thoracic diseases, including pneumonia.
- They use dense connections and batch normalization to make the optimization of such a deep network tractable.

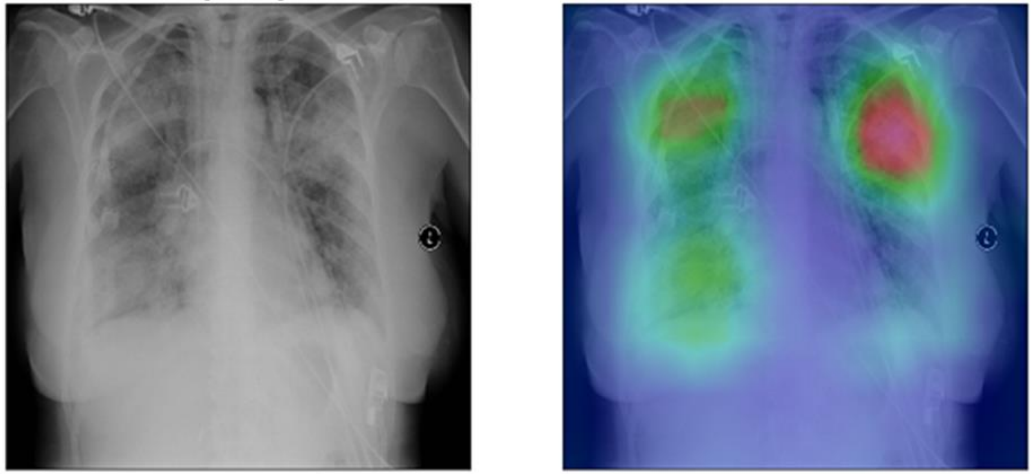


Chest X-Rays with different conditions with Heat map using GradCam



Original image GradCam++

Pneumonia



Original image GradCam++

Infiltration

Mass

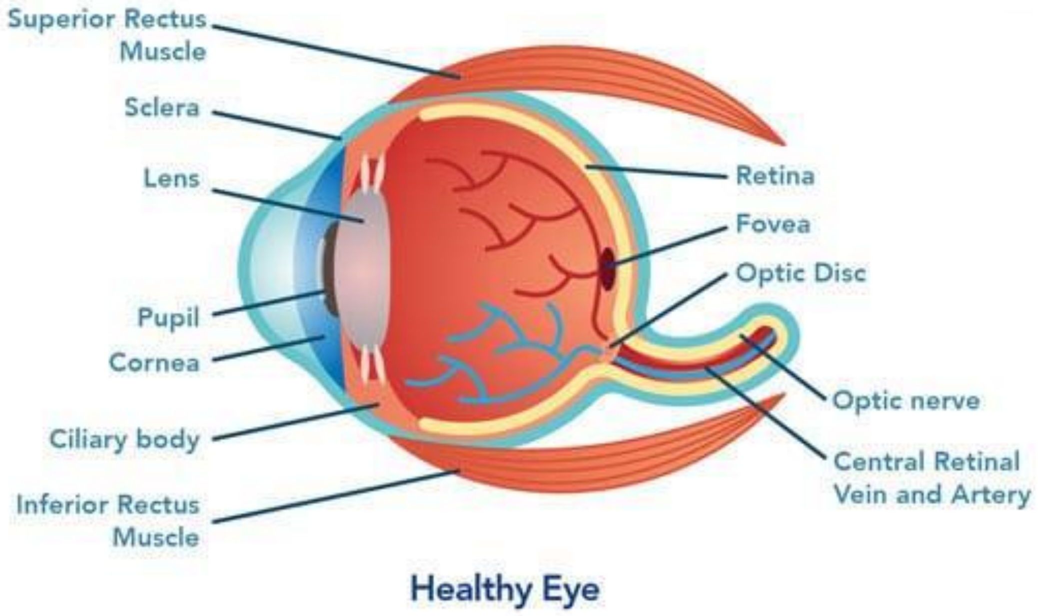
Comparison of results on large dataset of Chest X-rays

	Accuracy	Sensitivity	Specificity	AUC
ResNet50	80.0%	86.4%	76.7%	88.2% ($p < 0.001$)
Densenet-121	77.6%	86.9%	68.5%	87.1% ($p < 0.001$)
Inception-Resnet V2	77.6%	82.3%	71.5%	84.6% ($p < 0.001$)
Chexnet	72.1%	78.9%	64.3%	79.3% ($p < 0.001$)

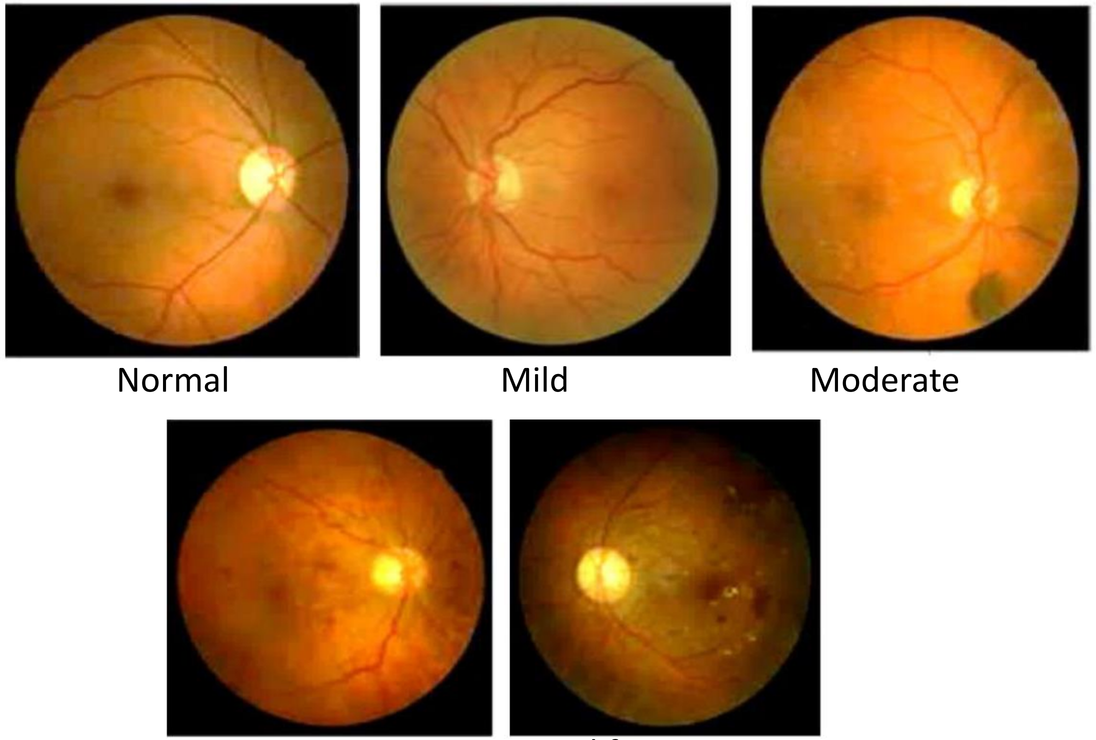
Diabetic retinopathy

- Diabetic retinopathy is caused by type II diabetes. When there is a high sugar in the blood can harm your retina, which leads to blindness or vision changes.
- Diabetic retinopathy is the leading cause of blindness worldwide, especially at the age of 30 to 70. Over 60% of diabetic patients will get diabetic retinopathy.
- People with diabetes are at higher risk for diabetic retinopathy, which causes damage to vessels at the back of the eyes
- Diabetic retinopathy will not occur suddenly, its progressive disease and the longer the uncontrolled blood sugars which lead to diabetic retinopathy,
- Automated diabetic retinopathy screening process will reduce the time, effort, and human errors.

Diabetic retinopathy



Comparison of different deep learning algorithms for detecting diabetic retinopathy



Normal Mild Moderate

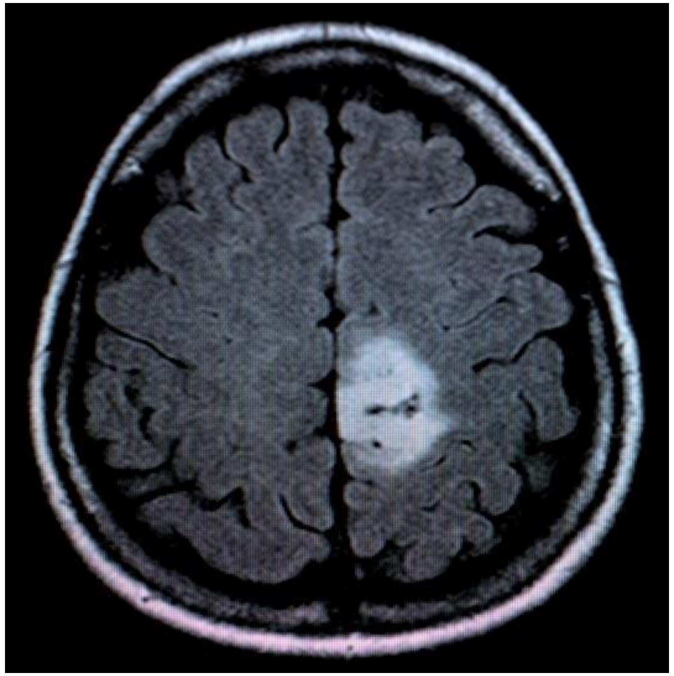
Serve Proliferative

Categories of Diabetic Retinopathy

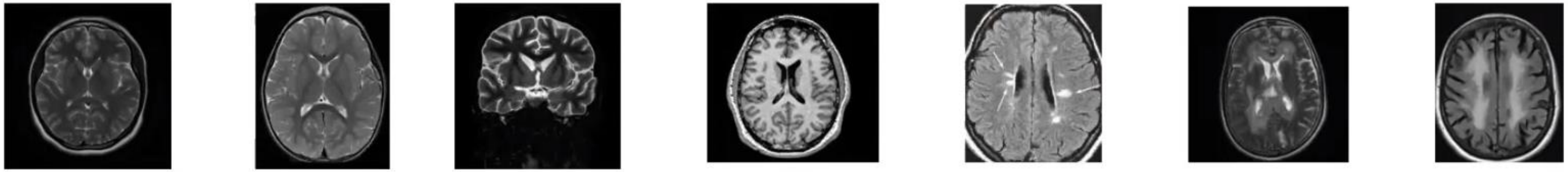
Model	SP	SE	AUC	ACC
AlexNet	94.07%	81.27%	0.9342	89.75%
VggNet-s	97.43%	86.47%	0.9786	95.68%
VggNet-16	94.32%	90.78%	0.9616	93.17%
VggNet-19	96.49%	89.31%	0.9684	93.73%
GoogleNet	93.45%	77.66%	0.9272	93.36%
ResNet	95.56%	88.78%	0.93.65	90.40%

Brain tumor detection using CNN

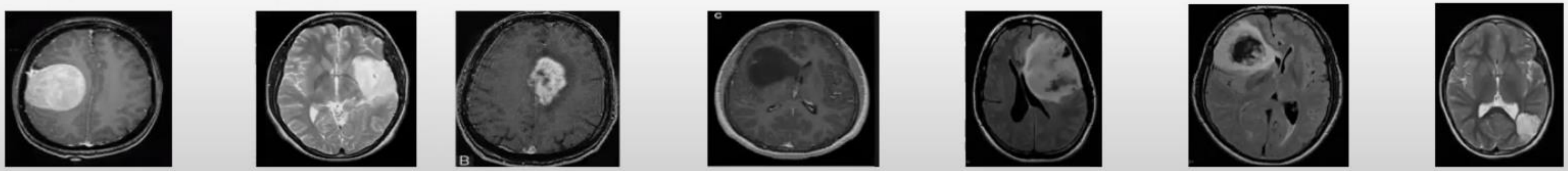
- Brain tumor is one of the most dangerous diseases which require early and accurately detection methods
- Now most detection and diagnosis methods depend on decision of neuro-specialists and radiologists for image evaluation which possible to human errors and time consuming
- The objective is to build a robust CNN model that can classify if the subject has a tumor or not based on Brain MRI scan images (here only T1 and T2W images are used) with an acceptable accuracy for medical grade application



Example of MRI images with and without Tumor



Controls (images without tumor)



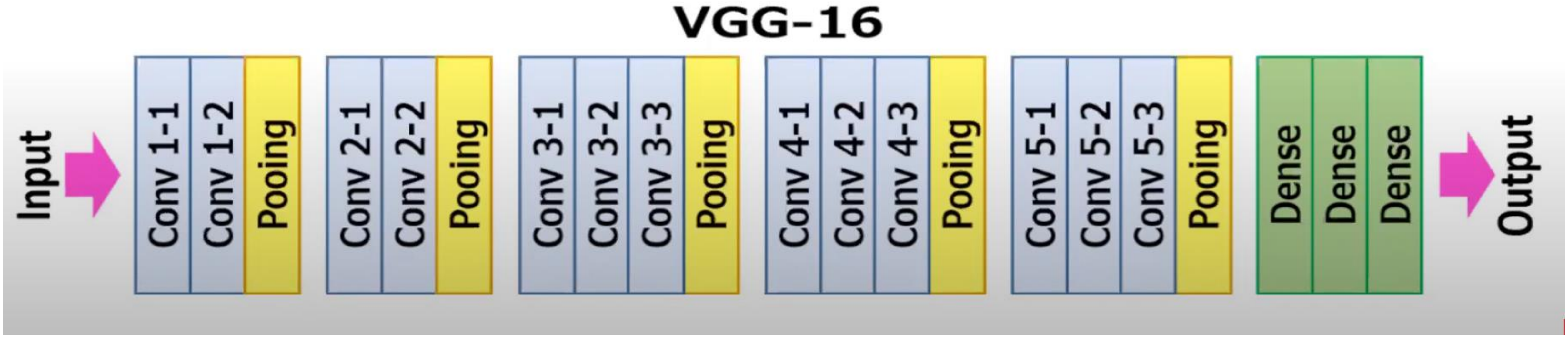
Patients (images with tumor)

Results – Comparison of different deep learning models

Model	TrainingAcc	ValAcc	Test Acc
MLP (Baseline)	85.2	76.89	63.2
SVC	89		89.48
SVC with HOG	95		94.68
CNN	92.1	92.46	90.04
VGG16	95.58	95.68	96.68
VGG16 unfreeze 1 layer	98.48	98.45	97.18
VGG16 unfreeze 3 layers	97.78	98.45	96.68
VGG16 unfreeze 2 layers	**99.14**	**99.65**	**97.36**
ResNet50	100	100	84.65
VGG19 unfreeze 3 layers	100	97.37	72.86
VGG19 unfreeze 1 layer	99.9	98	66.13

Results (Cont…)

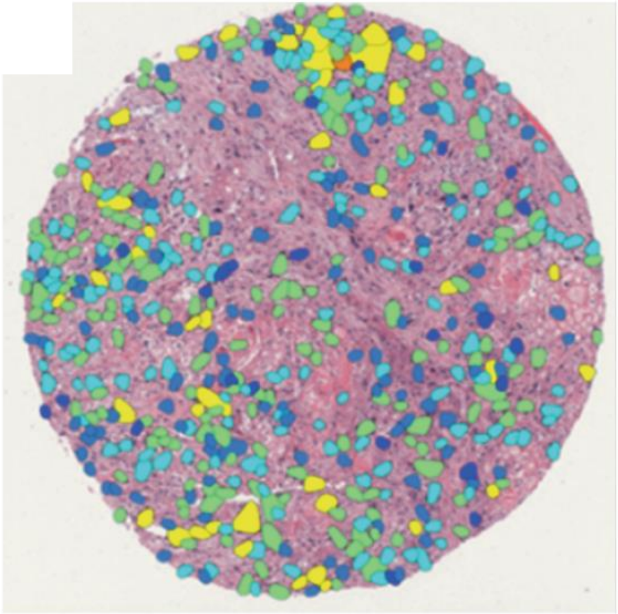
- VGG-16 performed better than other deep learning networks used for comparison



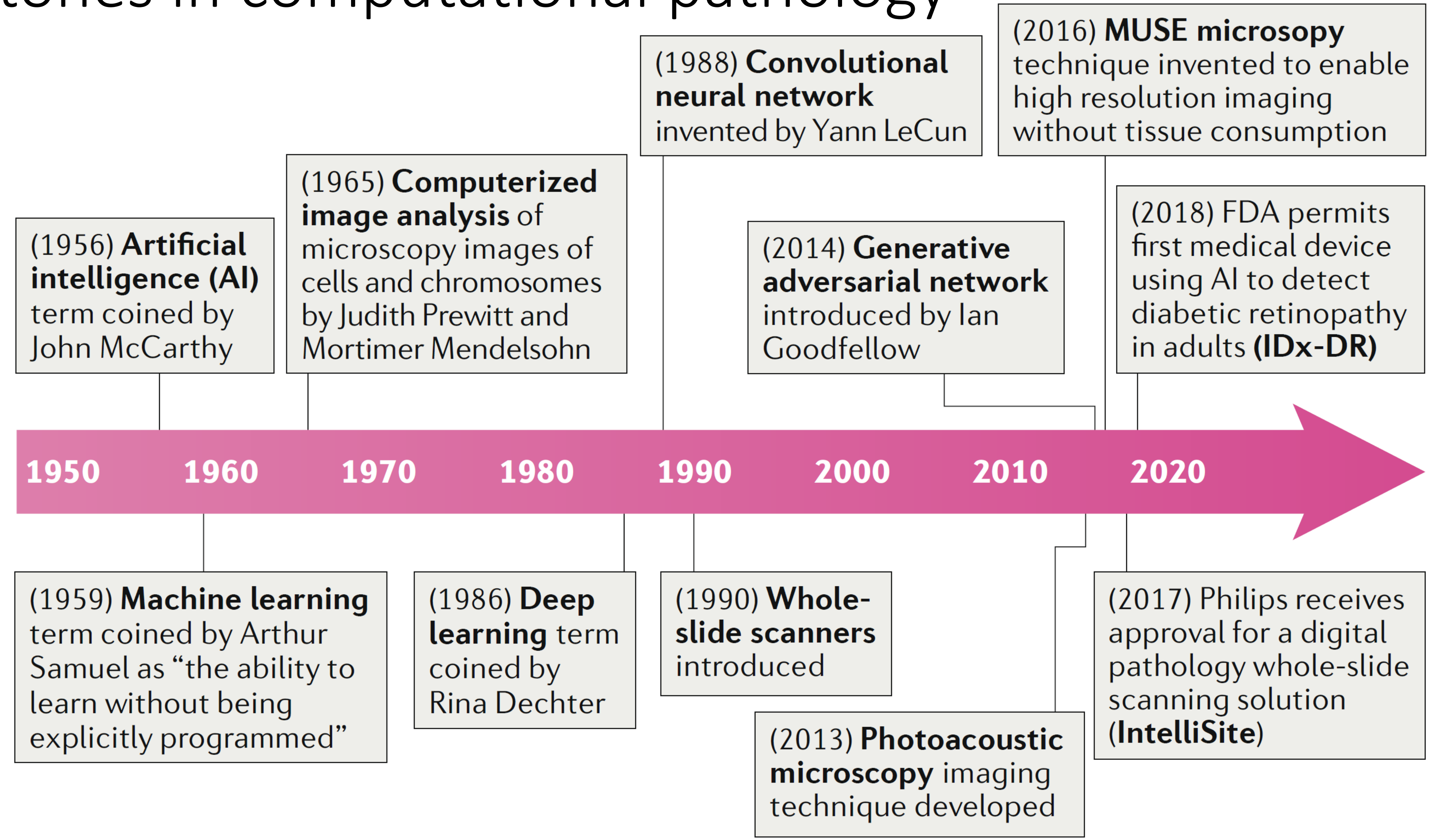
AI approaches in pathology

- In digital pathology, AI approaches have been applied to a variety of image processing and classification tasks:
  - Low-level tasks: focused around object recognition problems such as detection and segmentation
  - Higher-level tasks such as predicting disease diagnosis and prognosis of treatment response on the basis of patterns in the image.

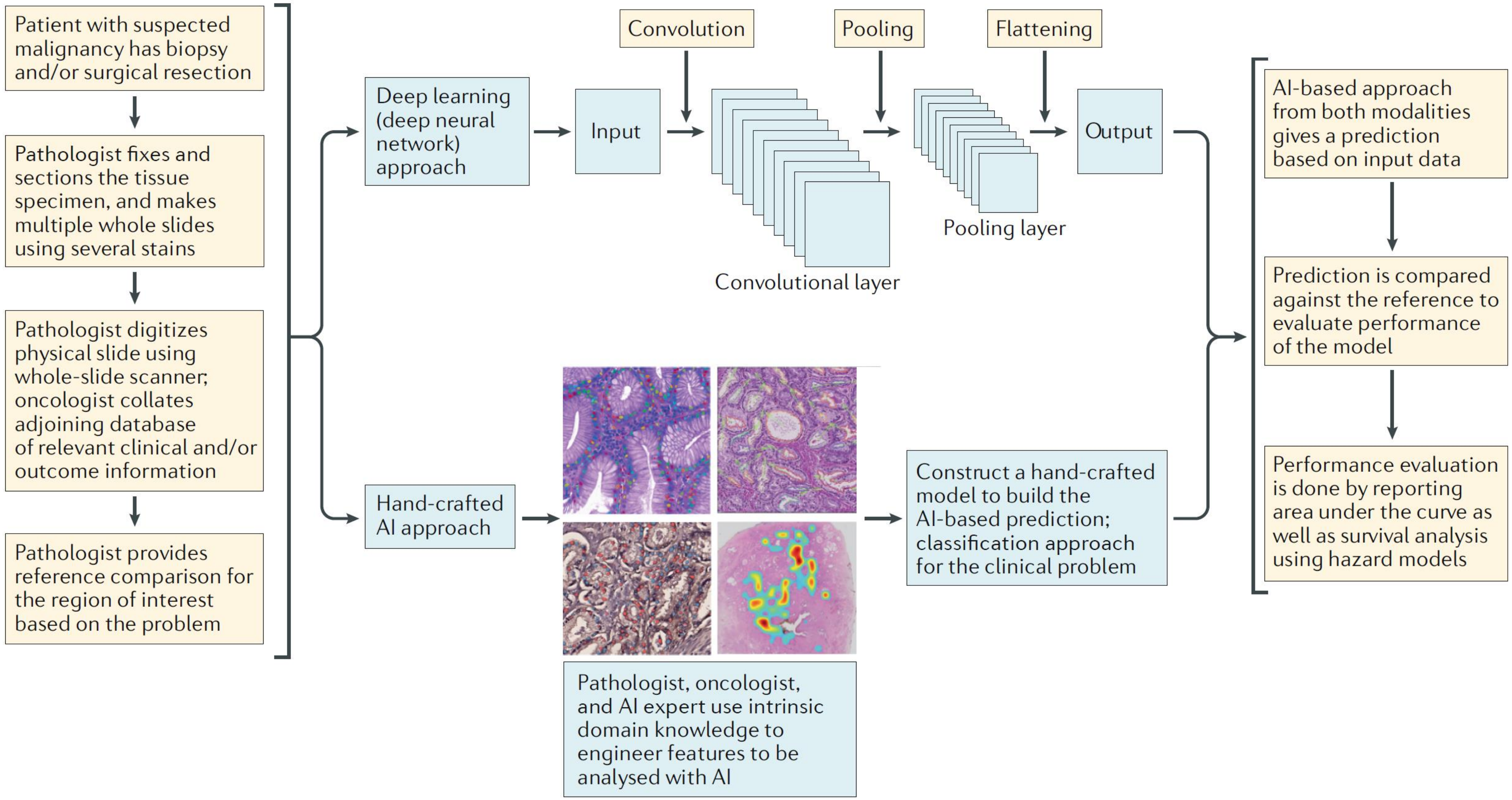
- AI approaches in digital pathology have been increasingly applied towards helping to address issues faced by oncologists, for example, evaluate disease severity and outcome as well as to predict response to therapy.

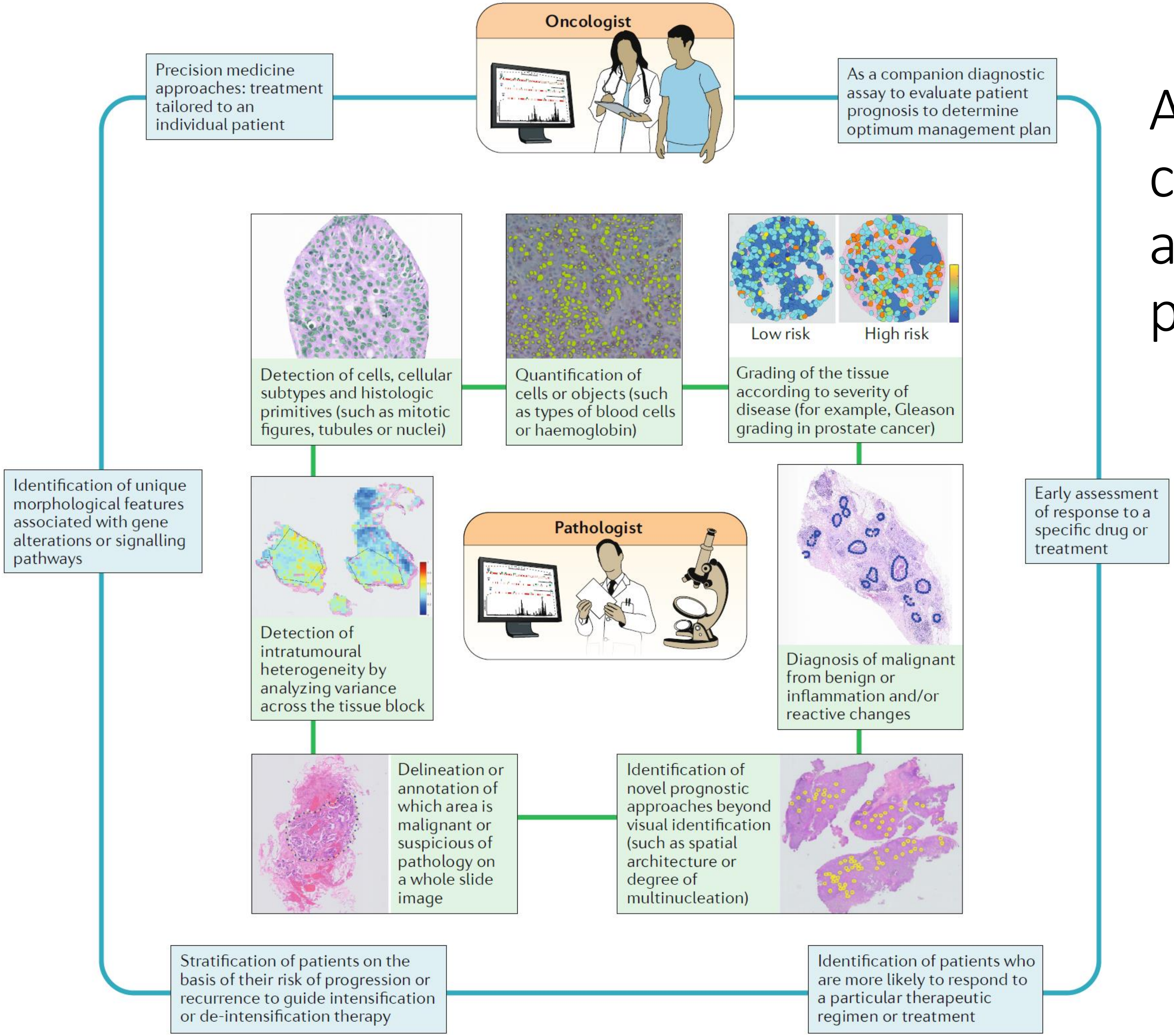


Milestones in computational pathology



Workflow and general framework for AI approaches in digital pathology





AI and ML approaches complement the expertise and support the pathologist and oncologist

AI in pathology

- The advent of whole-slide digital scanning and the concomitant rise of DL-based neural networks for interrogating digital images of slides has resulted in an explosion of interest in AI-based digital pathology technologies.
- Startups like PAIGE.AI, Proscia, DeepLens, PathAI and Inspirata are using DL-based AI tools for detection, diagnosis and prognosis of several cancer subtypes
- Interestingly, the landscape of digital pathology is, in parallel, also undergoing important innovation and rapid changes.
- The AI approaches that have been developed to date using 2D-stained slides would have to be suitably adapted to leverage the novel techniques that generate 3D images of the entire tissue, keeping in mind that a substantially larger volume of data would need to be analysed.
- Despite the challenges and obstacles, the potential of AI approaches for digital pathology is promising.

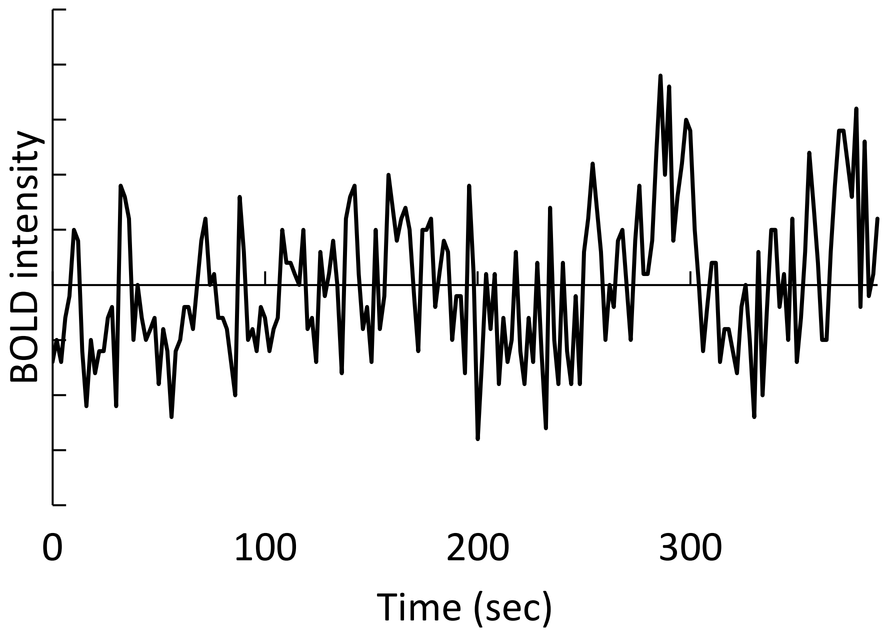
Oscillations in single seizure patients

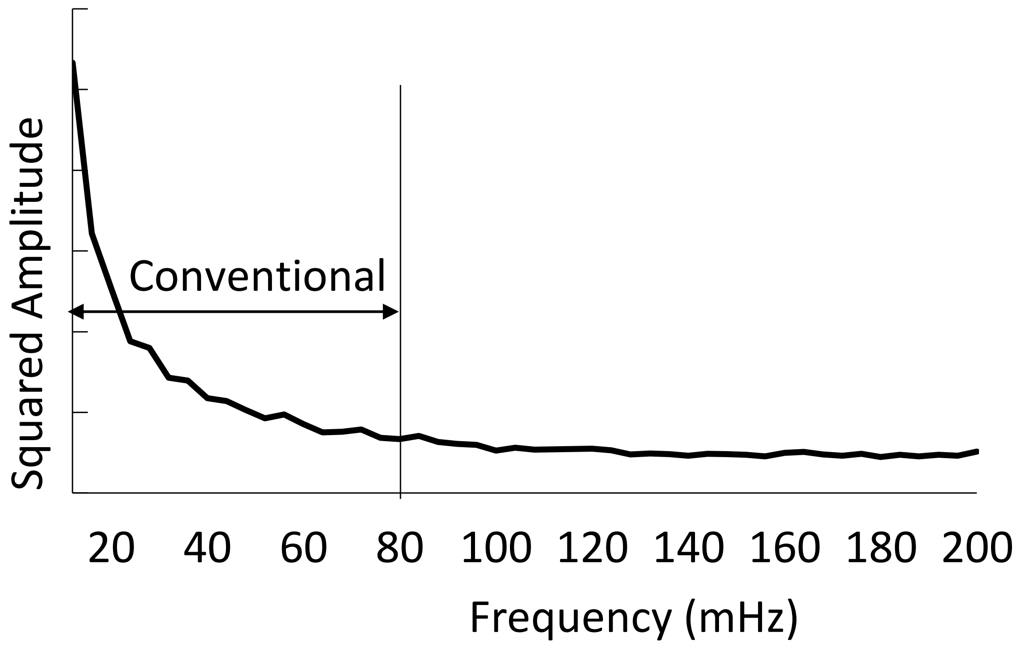
- Clinical problem
  - 4% of people will have one or more (non-febrile) seizures in their lifetime
  - 1% of these will end up having the diagnosis of epilepsy
  - Clinical assessment only seldom provides a definite diagnosis
  - Diagnostic tools are needed to discriminate between people with a first-ever seizure event from those with a seizure that precedes the onset of epilepsy

- Objectives:
  - Comparison of spontaneous fluctuations in single-seizure subjects, new onset epilepsy and healthy controls

- Analysis method:
  - Functional MRI based features
  - EEG based features
  - Machine learning based method by combining features from fMRI and EEG

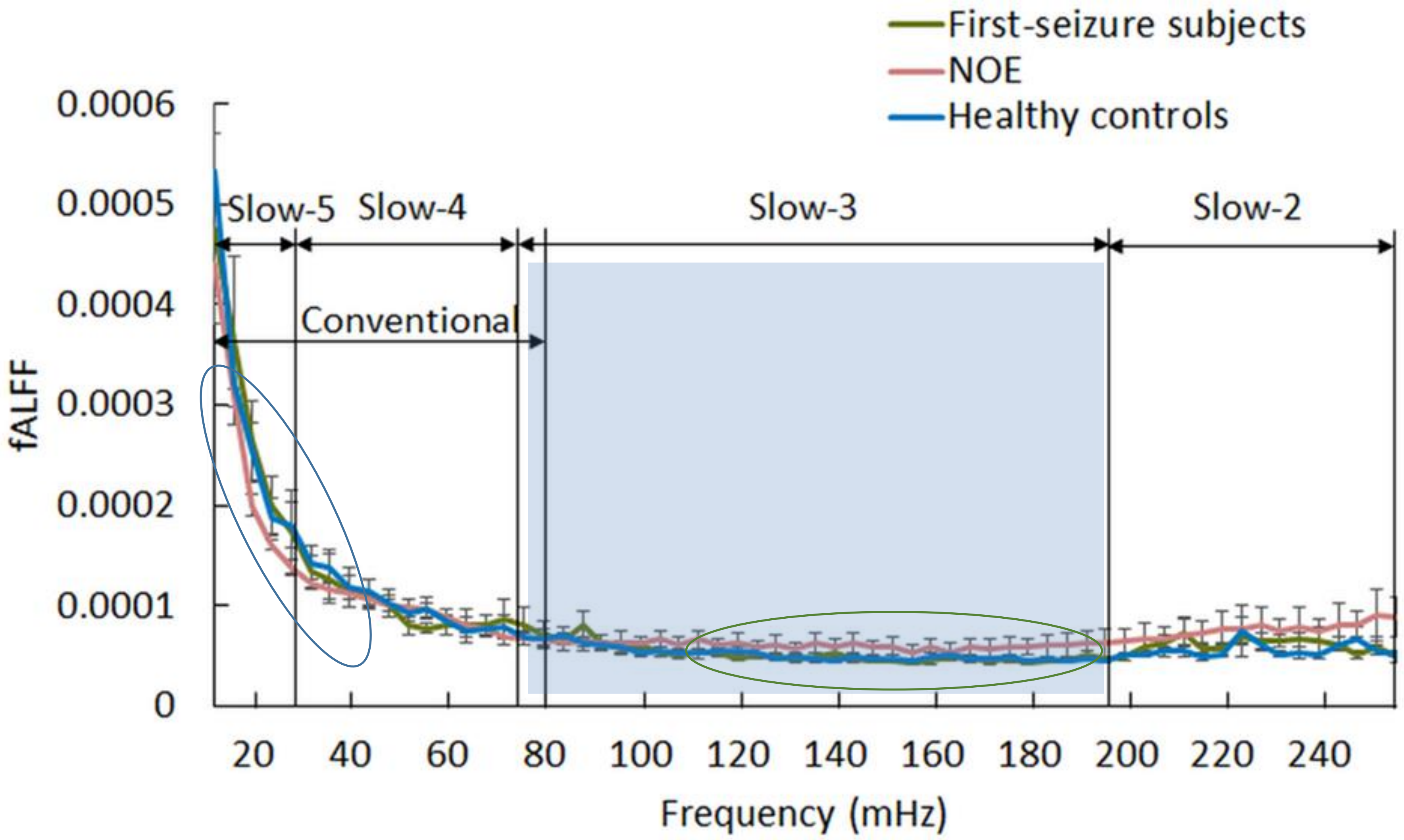
Average functional MRI signal from healthy brain



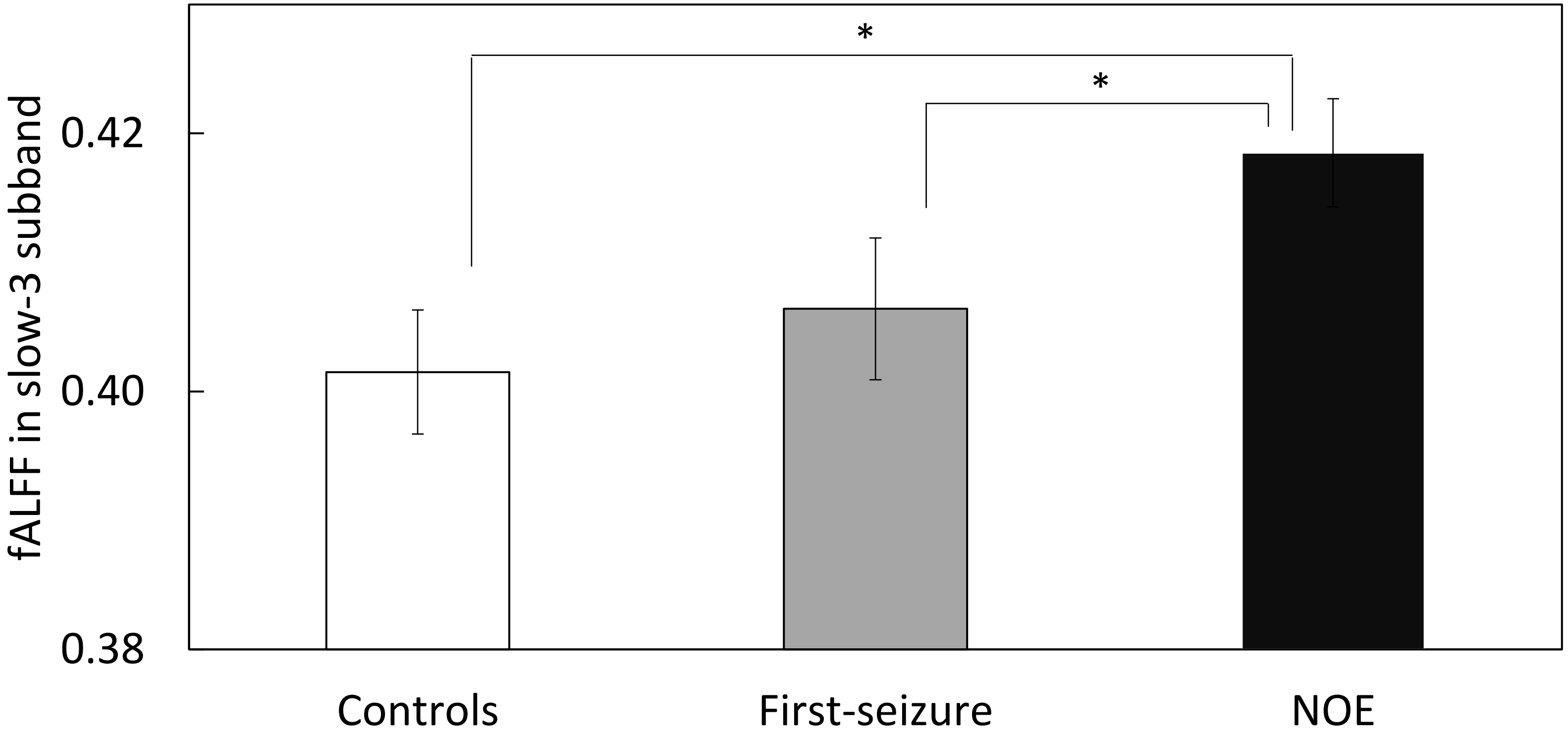


$$\text{fALFF} = \frac{\text{Total power in predefined frequancy range (10-80mHz)}}{\text{Total power in complete frequency range}}$$

Fractional amplitude of low frequency fluctuations (fALFF)



fALFF for differentiating between controls, first-seizure and epilepsy patients



Increase in fALFF in slow-3 subband

Combining fMRI and EEG features

- fMRI measures changes in the blood-oxygen level as an indirect consequence of neural activity, at a typical sampling rate of 500 mHz.
- EEG has a superior temporal resolution allowing analysis of high frequency temporal activity, fMRI has the advantage of a high spatial resolution providing insights into specific brain structures, including deep regions.
- Therefore, EEG and fMRI measurement could ideally complement each other in the diagnosis of epilepsy.
- The goal of this study is to assess the diagnostic value of physiological signals measured using EEG and/or functional MRI using a classification model.

EEG and fMRI features

		First-seizure	Epilepsy	t-statistic
EEG				
	PLI delta band (HV) (mean ± SD)	.115 ± 0.01	.121 ± 0.01	1.88
	PLI upper beta band (rest) (mean ± SD)	.060 ± 0.01	.065 ± 0.01	1.39
	SL theta band (HV) (mean ± SD)	.104 ± 0.02	.096 ± 0.02	1.22
	Coherence lower alpha band (rest) (mean ± SD)	.375 ± 0.09	.347 ± 0.05	1.15
fMRI				
	Slow 2 thalamus (mean ± SD)	.071 ± 0.02	.086 ± 0.03	1.79
	Slow 5 thalamus (mean ± SD)	.358 ± 0.05	.326 ± 0.06	1.64
	Conv. Thalamus (mean ± SD)	.659 ± 0.05	.631 ± 0.08	1.21
	Gamma 70% sparse networks (mean ± SD)	1.38 ± 0.66	1.19 ± 0.16	1.18

The sensitivity and specificity (mean ± SD) of the SVM classifier with both EEG and fMRI features are 75 ± 19% and 83 ± 17%, respectively. Using only the EEG features resulted in a sensitivity of 73 ± 21% and specificity of 78 ± 20%. While, the classifier with only the fMRI features has a sensitivity of 70 ± 28% and a specificity of 67 ± 25%.

How can AI based medical technology become part of an everyday practice?

- AI needs to penetrate the boundaries of evidence-based medicine, the lack of policies and reluctance from medical professionals to use it.
- A.I. will only reach the status of an everyday medical technology if medical associations provide clear guidelines about implementing it
- Every A.I.-based technology that is considered for use in healthcare must be regulated, efficient and backed by evidence
- There have been discussions around a new regulatory framework for modifications to A.I./machine learning-based software as a medical device (SaMD). This could potentially lead to regulations that make it possible for regulators to assess companies while the companies can roll out algorithms and updates without the need to check them all.
- if policy makers create policies that favor adoption and if the medical community does not look at A.I. as a threat, but rather, as the stethoscope of the 21st century.
- The core of the medical profession is and still will be the human touch, empathy and compassionate care; attributes that are almost impossible to mimic through a programming language

What are the major challenges ahead?

- Interpretability: Despite high accuracy AI based methods face challenges regarding the lack of interpretability and contrasting traditional methods.
- Quality, quantity of data and Biased AI: Prior to clinical adoption, AI-based and ML-based tools need to be sufficiently validated using multi-institutional and clean data in order to ensure generalizability of the approaches.
- Reimbursement and clinical adoption: Reimbursement of the costs of performing/using AI-based methods needs to be resolved.
- Trust and privacy issues: AI based methods requires trust of patients and clinicians for usage and data sharing.
- Regulatory, legal issues and liability: The key principle guiding the approval process in most countries is the requirement of ‘an explanation of how the software works’; this is obviously crucial for DL-based AI approaches, which are perceived as being a ‘black-box’ and lacking interpretability.

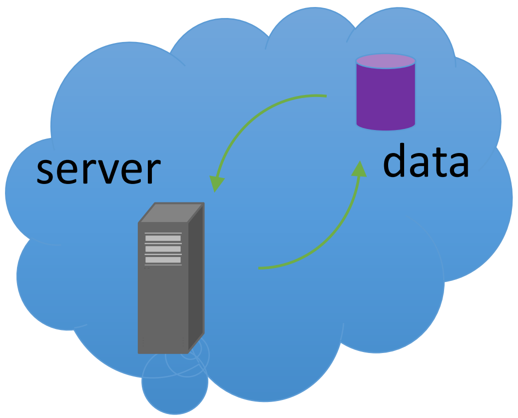
Federated Learning

Federated Learning

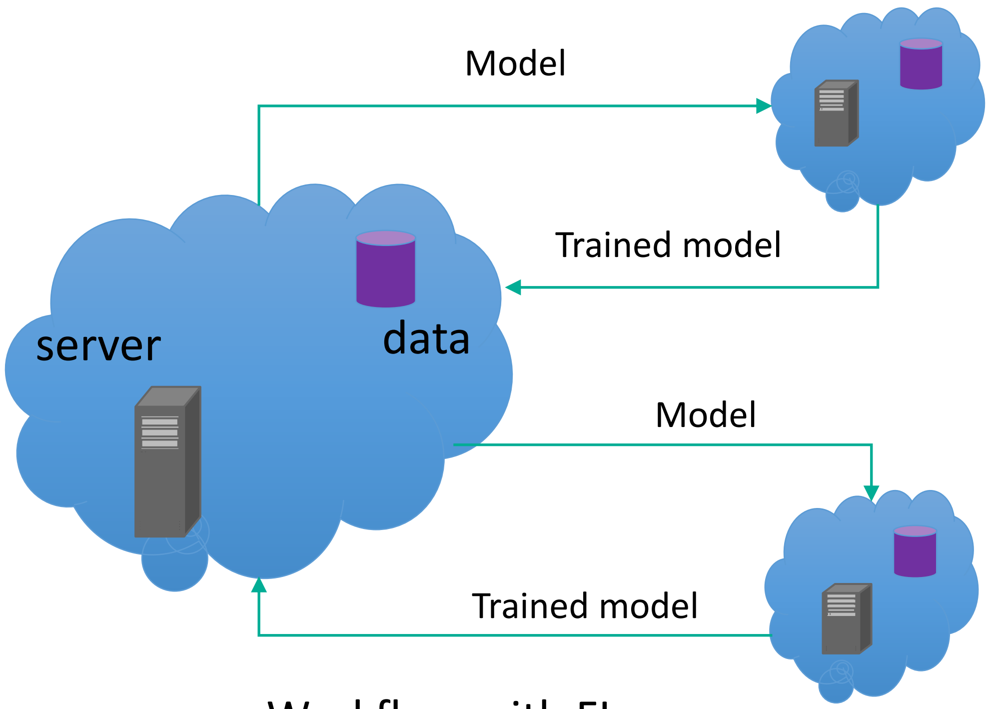
- Challenges around data sharing, privacy of data, quantity of data and biased AI due to data sharing issues can be resolved using Federated Learning Architectures for AI model training
  - Large curated datasets are required to achieve clinical-grade accuracy while being safe, fair and equitable and generalizing well to unseen data.
  - It is difficult to obtain large healthcare data due to privacy concerns.
  - Another issue is collecting, curating, and maintaining a high-quality dataset takes considerable time, effort and expense.
  - Data originated from only few sources can introduce bias and technical imbalances which adversely affect accuracy for certain groups or sites.

Federated Learning - Introduction

- Federated learning (FL) is a learning paradigm seeking to address the problem of data governance and privacy by training algorithms without exchanging data.

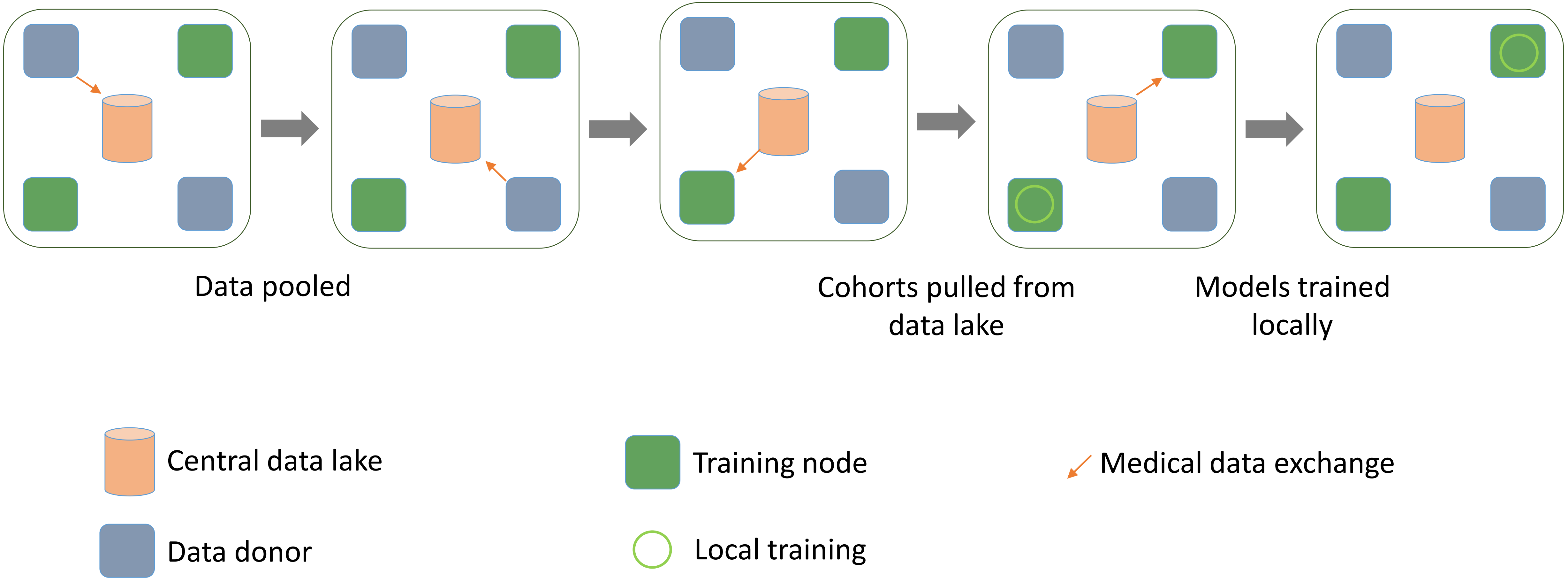


Workflow without FL

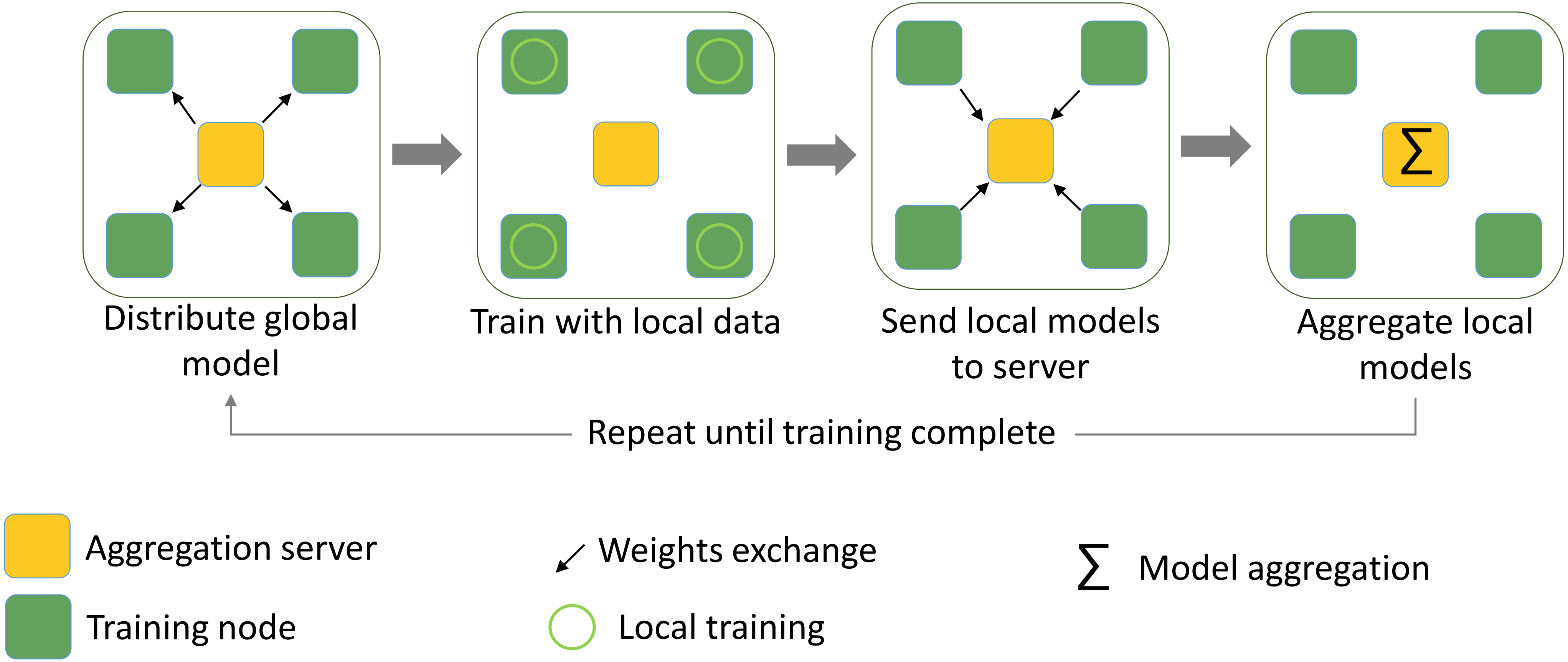


Workflow with FL

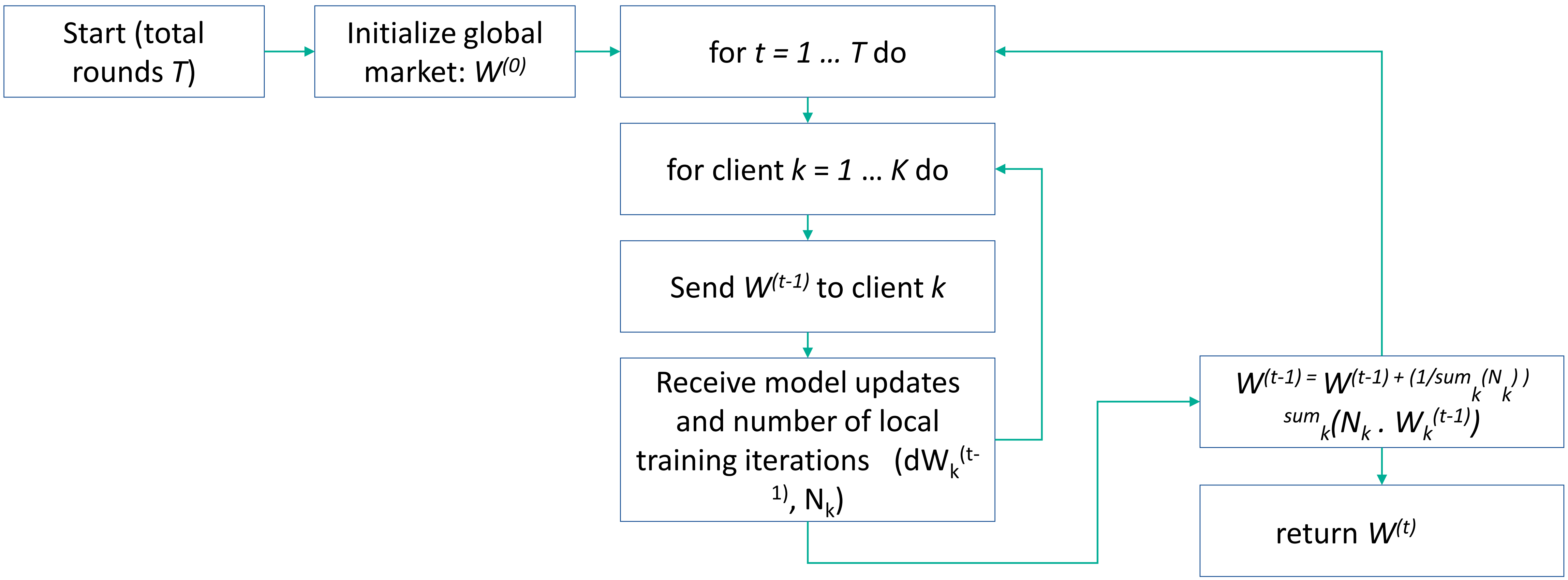
Centralized Data Lake Training



FL Based Workflow - Aggregation Server Architecture



Algorithm - Aggregation Server Architecture



Advantages and challenges of FL

- Advantages
  - Address privacy and data governance challenges by enabling ML from non-co-located data
  - Benefit with large amounts of data.

- Challenges
  - Computing facilities are required within the hospital.
  - AI developer can not investigate on individual samples to understand why model is failing.
  - Inhomogeneous data distribution poses a challenge for FL algorithms and strategies.

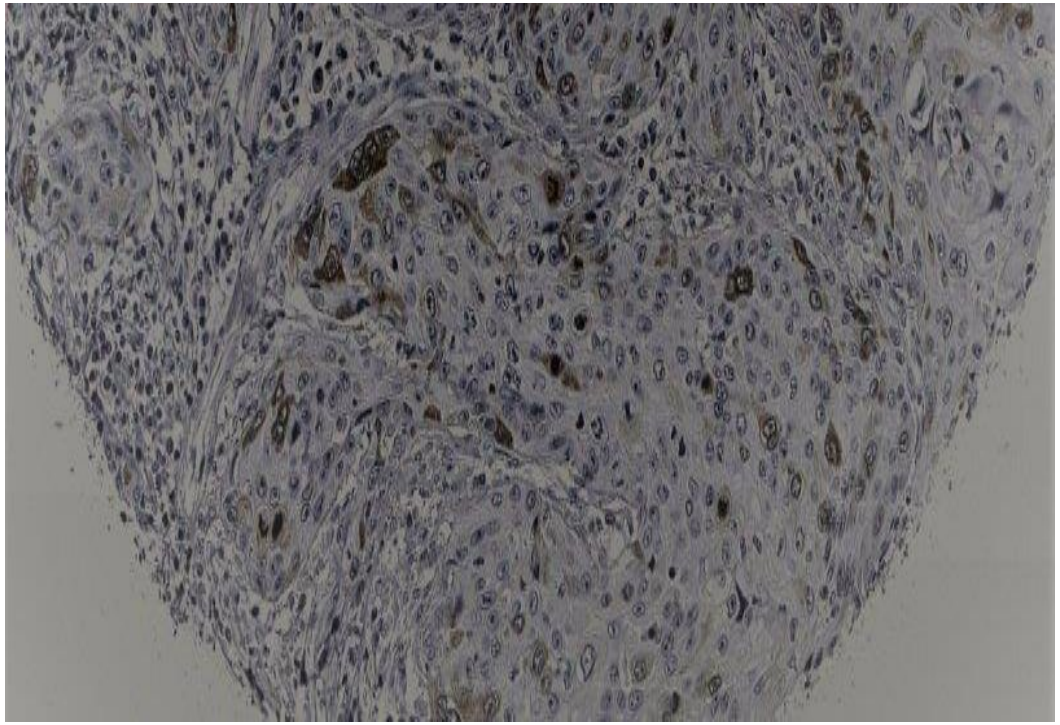
Selected AI healthcare companies

Applications of AI in healthcare

- Improving in-person and online consultations
- Health assistance and medication management
- A.I.-driven diagnostics
- Mining medical records
- Precision medicine
- Designing treatment plans
- Drug creation
- Triage tools

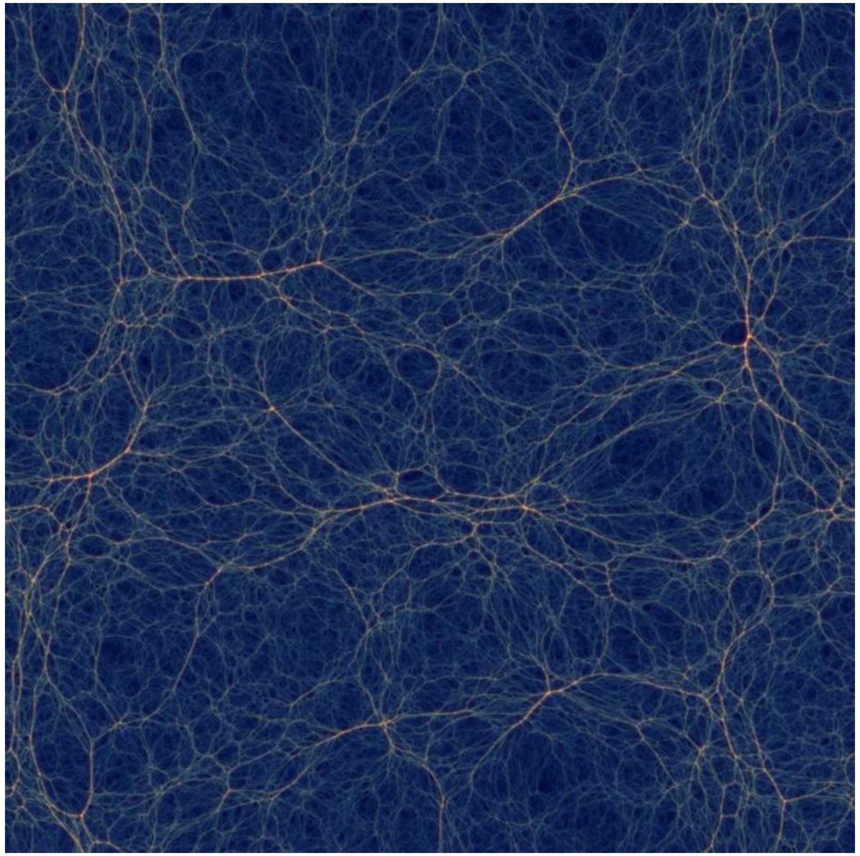
AI Companies in healthcare

- PATHAI
  - MORE ACCURATE **CANCER** DIAGNOSIS WITH AI
  - Location: Cambridge, Massachusetts
  - How it's using AI in healthcare: PathAI is developing machine learning technology to assist **pathologists** in making **more accurate diagnoses**. The company's current goals include reducing error in cancer diagnosis and developing methods for individualized medical treatment.
  - PathAI has worked with drug developers like Bristol-Myers Squibb and organizations like the Bill & Melinda Gates Foundation to expand its AI technology into other healthcare industries.



AI Companies in healthcare (Cont…)

- ENLITIC
  - AI DEEP LEARNING FOR ACTIONABLE INSIGHTS
  - Location: San Francisco, California
  - How it's using AI in healthcare: Enlitic develops deep learning medical tools to streamline radiology diagnoses. The company’s deep learning platform analyzes **unstructured medical data (radiology** images, blood tests, EKGs, genomics, patient medical history) to give doctors better insight into a patient’s **real-time needs**.
  - MIT named Enlitic the 5th smartest artificial intelligence company in the world, ranking above Facebook and Microsoft.

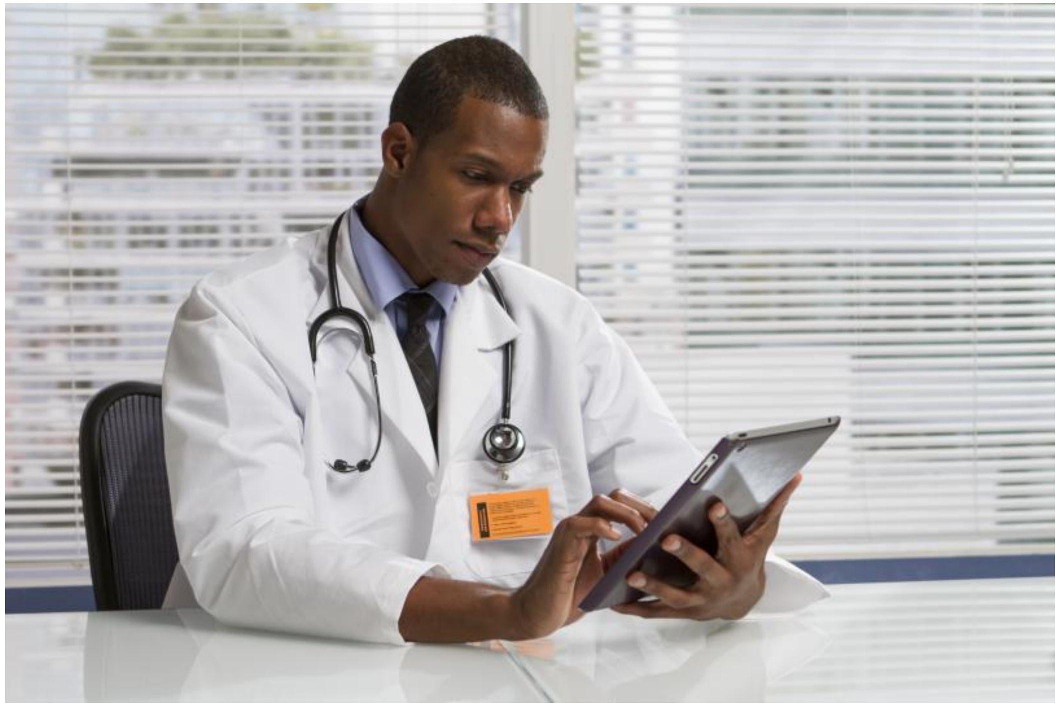


AI Companies in healthcare (Cont…)

- ZEBRA MEDICAL VISION
  - AI-POWERED RADIOLOGY ASSISTANT
  - Location: Shefayim, Israel
  - How it's using AI in healthcare: Zebra Medical Vision provides **radiologists with an AI-enabled assistant** that receives imaging scans and automatically analyzes them for various clinical findings it has studied. The findings are passed onto **radiologists**, who take the assistant's reports into consideration when making a diagnosis.

AI Companies in healthcare (Cont…)

- BIOXCEL THERAPEUTICS
  - AI IN BIOPHARMACEUTICAL DEVELOPMENT
  - Location: New Haven, Connecticut
  - How it's using AI in healthcare: BioXcel Therapeutics uses AI to identify and develop new medicines in the fields of **immuno-oncology and neuroscience**. Additionally, the company's **drug re-innovation** program employs AI to find new applications for existing drugs or to identify new patients.
  - BioXcel Therapeutics' work in AI-based drug development was named as one of the "Most Innovative Healthcare AI Developments of 2019."

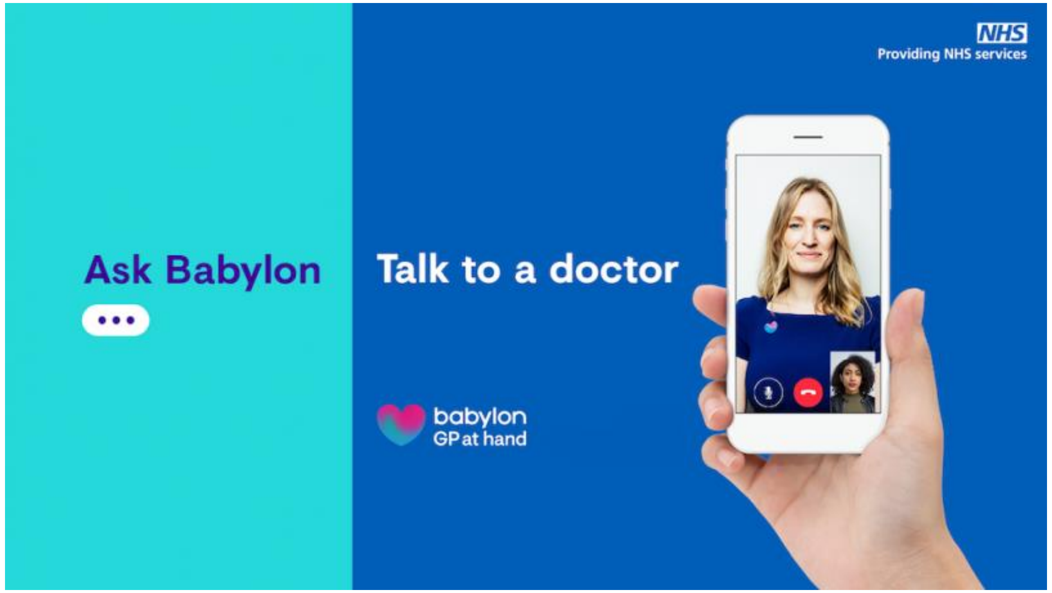


AI Companies in healthcare (Cont…)

- BERG HEALTH
  - TREATING RARE DISEASE WITH AI
  - Location: Framingham, Massachusetts
  - How it's using AI in healthcare: BERG is a clinical-stage, AI-based biotech platform that **maps diseases** to accelerate the discovery and development of **breakthrough medicines**. By combining its “Interrogative Biology” approach with traditional R&D, BERG can develop more robust product candidates that **fight rare diseases**.
  - BERG recently presented its findings on Parkinson’s Disease treatment — they used AI to find links between chemicals in the human body that were previously unknown — at the Neuroscience 2018 conference.

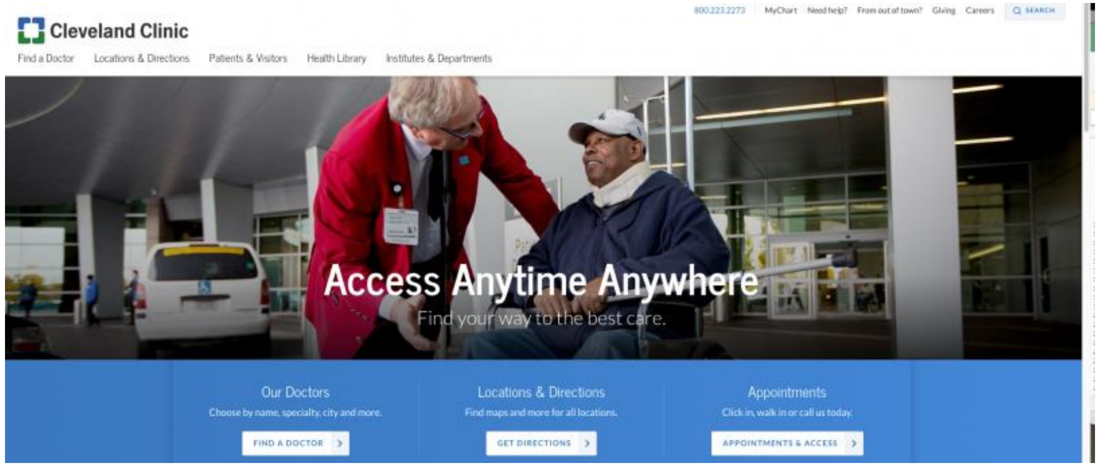
AI Companies in healthcare (Cont…)

- BABYLON HEALTH
  - INCREASING ACCESS TO HEALTHCARE
  - Location: New York, New York
  - How it's using AI in healthcare: Babylon uses AI to provide personalized and interactive healthcare, including anytime face-to-face appointments with doctors. The company’s AI-powered **chatbot** streamlines the review of a **patient’s symptoms, then recommends either a virtual check-in or a face-to-face visit with a healthcare professional**.
  - Babylon and Canada's Telus Health teamed up to develop a Canada-specific AI app that scans a patient’s survey answers, then connects them via video with the right healthcare provider or professional.



AI Companies in healthcare (Cont…)

- CLEVELAND CLINIC
  - PERSONALIZED HEALTHCARE PLANS WITH AI
  - Location: Cleveland, Ohio
  - How it's using AI in healthcare: The Cleveland Clinic teamed up with IBM to infuse its IT capabilities with artificial intelligence.
  - The world-renowned hospital is using AI to gather information on trillions of administrative and health record data points to streamline the patient experience. This marriage of AI and data is helping the Cleveland Clinic **personalize healthcare plans** on an individual basis.



AI Companies in healthcare (Cont…)

- TEMPUS
  - A MASSIVE DATA LIBRARY FOR PERSONALIZED HEALTH
  - Location: Chicago, Illinois
  - How it's using AI in healthcare: Tempus is using AI to sift through the world's largest collection of clinical and molecular data in order to personalize healthcare treatments. The company is developing **AI tools** that collect and analyze data in everything from **genetic sequencing to image recognition**, that can give physicians better insights into treatments and cures.
  - Tempus is currently using its AI-driven data to tackle cancer research and treatment.

AI Companies in healthcare (Cont…)

- PROSCIA
  - LOOKING AT THE DATA BEHIND THE MEDICAL IMAGE
  - Location: Philadelphia, Pennsylvania
  - How it's using AI in healthcare: Proscia is a digital **pathology platform** that uses AI to detect patterns in **cancer cells**. The company’s software helps pathology labs eliminate bottlenecks in data management and uses AI-powered image analysis to connect data points that support cancer discovery and treatment.
  - Proscia recently raised $8.3M in Series A funding that will be used to expand deployment of the company’s digital pathology software and AI tools.

AI Companies in healthcare (Cont…)

- IBM
  - WATSON'S SIDE GIG HELPING HOSPITALS
  - Location: Armonk, N.Y.
  - How it's using AI in healthcare: When IBM’s Watson isn’t competing on Jeopardy!, it's helping healthcare professionals harness their data to optimize hospital efficiency, better engage with patients and improve treatment.
  - Watson is currently applying its skills to everything from developing **personalized health plans to interpreting genetic testing results and catching early signs of disease**.

AI Companies in healthcare (Cont…)

- GOOGLE DEEPMIND HEALTH
  - ALERTING DOCTORS WHEN PATIENT'S ARE IN TROUBLE
  - Location: London, England
  - How it's using AI in healthcare: Google's DeepMind Health AI software is being used by hospitals all over the world to help move patients from testing to treatment more efficiently.
  - The DeepMind Health program **notifies doctors when a patient's health deteriorates** and can even help in the diagnosis of ailments by combing its massive dataset for comparable symptoms. By collecting symptoms of a patient and inputting them into the DeepMind platform, doctors can diagnose quickly and more effectively.

AI Companies in healthcare (Cont…)

- VICARIOUS SURGICAL
  - VIRTUAL REALITY-ENABLED ROBOTICS FOR SURGERY
  - Location: Charlestown, Massachusetts
  - How it's using AI in healthcare: Vicarious Surgical combines **virtual reality with AI-enabled robots so surgeons** can perform minimally invasive operations. Using the company's technology, surgeons can virtually shrink and explore the inside of a patient's body in much more detail.
  - Vicarious Surgical's technology impressed former Microsoft chief Bill Gates, who invested in the company.

AI Companies in healthcare (Cont…)

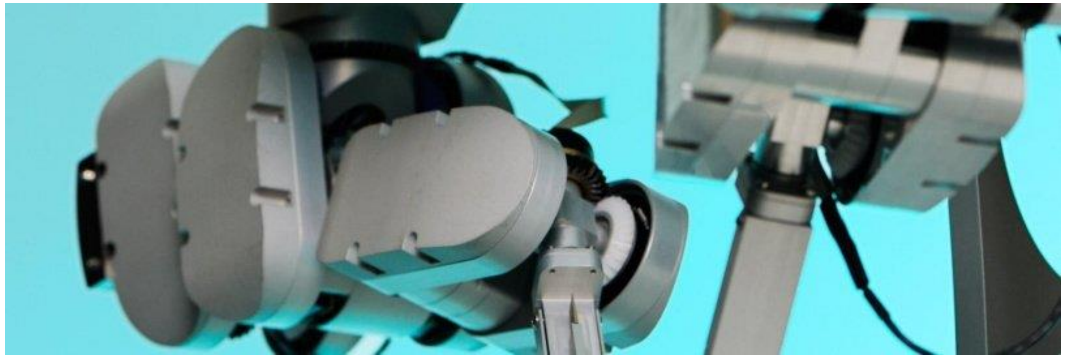
- AURIS HEALTH
  - AI ROBOTS REVOLUTIONIZING ENDOSCOPY
  - Location: Redwood City, California
  - How it's using AI in healthcare: Auris Health develops a variety of robots designed to improve **endoscopies** by employing the latest in micro-instrumentation, endoscope design, data science and AI. Consequently, **doctors get a clearer view of a patient's illness** from both a physical and data perspective.
  - The company is developing AI robots to study lung cancer, with the goal of curing it someday.

AI Companies in healthcare (Cont…)

- ACCURAY
  - PRECISION ROBOTIC TREATMENT FOR TREATING CANCER
  - Location: Sunnyvale, California
  - How it's using AI in healthcare: The Accuray CyberKnife System uses robotic arms to precisely **treat cancerous tumors** all over the body. Using the robot's real-time tumor tracking capabilities, doctors and surgeons are able to treat only affected areas rather than the whole body.
  - The Accuray CyberKnife robot uses 6D motion-sensing technology to aggressively **track and attack cancerous tumors** while saving healthy tissue.

AI Companies in healthcare (Cont…)

- MICROSURE
  - IMPROVING SURGICAL PRECISION
  - Location: Eindhoven, The Netherlands
  - How it's using AI in healthcare: MicroSure's robots help surgeons overcome their human physical limitations.
  - The company's motion stabilizer system reportedly improves **performance and precision during surgical procedures**. Currently, eight of MicroSure's micro-surgical operations are approved for lymphatic system procedures.



AI Companies in healthcare (Cont…)

- H2O.AI
  - AI FOR DATA THROUGHOUT THE HEALTH SYSTEM
  - Location: Mountain View, California
  - How it's using AI in healthcare: H2O.ai’s AI analyzes data throughout a healthcare system to mine, automate and predict processes. It has been used to predict ICU transfers, improve clinical workflows and even pinpoint a patient’s risk of hospital-acquired infections.
  - Using the company’s artificial intelligence to mine health data, hospitals can **predict and detect sepsis**, which ultimately reduces death rates.