

Artificial Intelligence for Medical Imaging 2020

Market and Technology
Report 2020

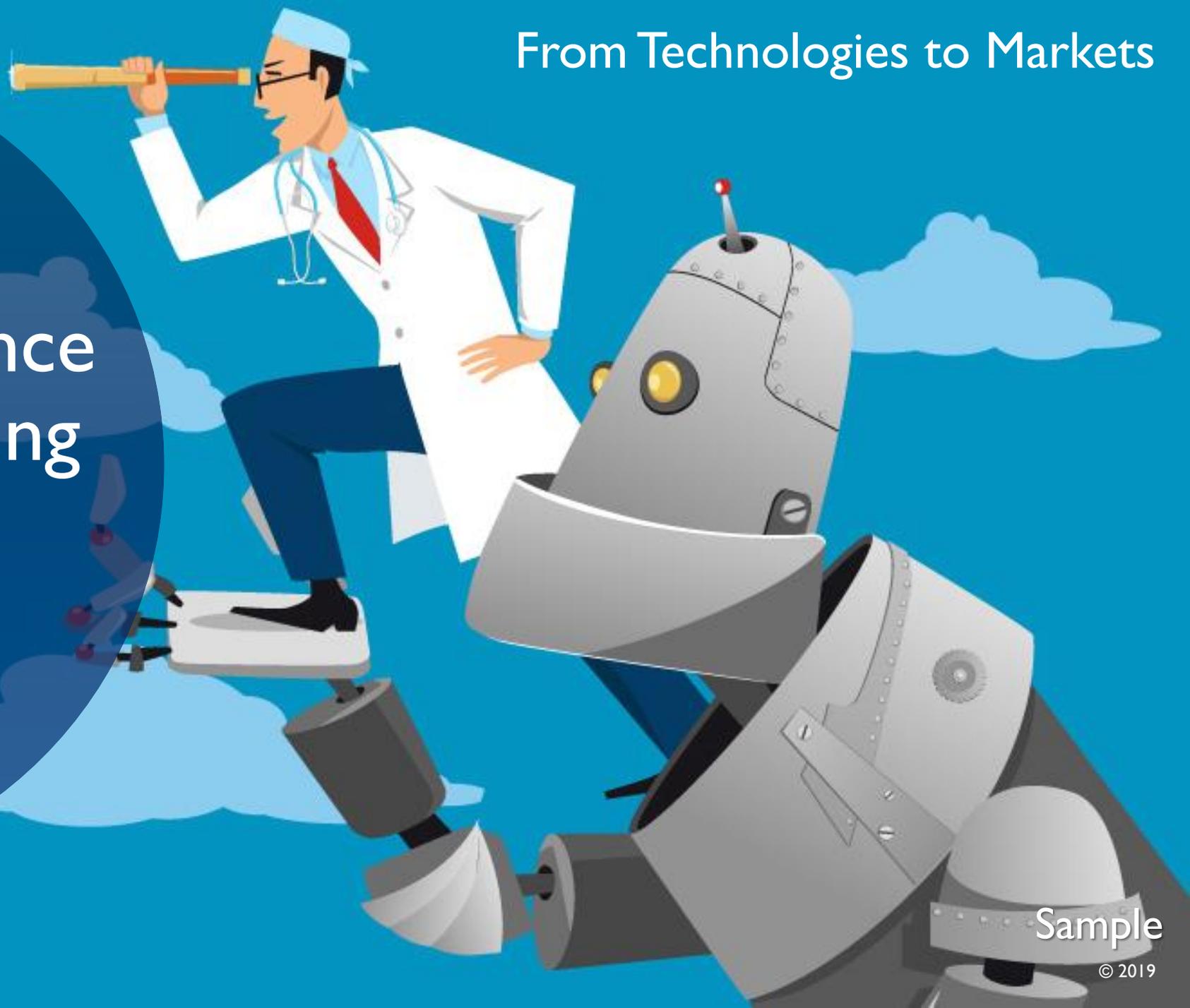


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REPORT OBJECTIVES

- Provide an overview of the market of AI in the field of medical imaging in terms of number of algorithms deployed and the value they generate for every player involved, at medical device level, AI platform level, and algorithm development level along with the understanding of the ecosystem, technologies used, strategic positioning, and how these will evolve in the coming years.
- Present the current market data and forecasts depending on the modality studied such as MRI and CT scans, and its application in the patient diagnostic process, such as noise reduction, screening or diagnostics, in dollar value and volume of images analyzed.
- Identify where the opportunities lie for each type of player along with a detailed description of the regulations and constraints of this field. In addition to the current overview, an introduction of the evolution of those regulations in the coming years is presented.
- Discuss the different technologies currently used, the business models and technical constraints inherent to the medical imaging field as well as trends for the integration of AI in fields other than radiology.

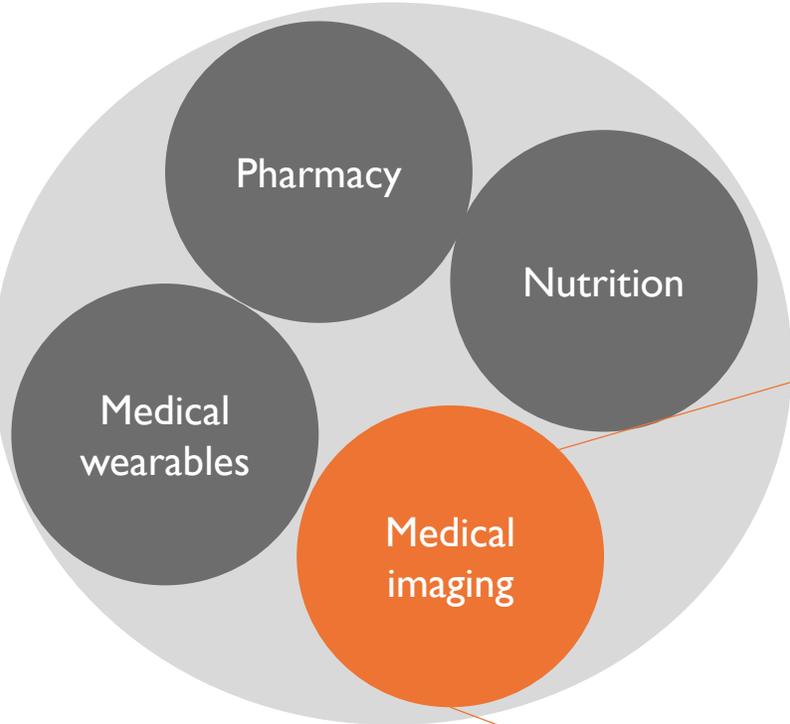
COMPANIES CITED IN THIS REPORT

4quant, 16bit, Advantis, ai analysis inc, Aidence, Aidoc, Amazon, Aquila medical innovation, Arterys, Ascension, Avalon AI, Azmed, Balzano, Behold.ai, Blackford analysis, Brainminer, BrainScan, Butterfly network, Canon, Caption health, Carestream, Cercare medical, Circle cardiovascular imaging, Contextflow, Corindus Vascular robotics, Curacloud, Curemetrix, Deepcare, DeepMind, Deepnoid, Deepradiology, Deepwise, Densitas, Deski, Dia imaging analysis, Dr CADx, eko.ai, Enlitic, Fujifilm, GE healthcare, Gleamer, Google, Healthmyne, Hearthflow, IBM, Icometrix, Idx, Image biopsy lab, Imbio, Incepto, Infervision, Infinitt healthcare, Innovationdx, Intel, Johnson & Johnson, Kheiron medical technologies, Koios, LPixel, Lunit, maxQ, Mazor robotics, MD.ai, Medtronic, Mellanox technologies, Methinks, Microsoft, Neuropsychad, Nuance, NVidia, Optellum, Oracle, Oxipit, Perceiv.ai, Peredoc, Perspectum, Philips, Pixyl, Predible, Qmenta, Quantib, Quantitative insights, Quibim, Qure.ai, Samsung, Screenpoint, Siemens, Terarecon, Therapanacea, Therapixel, Ultromics, Verb surgical, Vida, Viz.ai, Volpara solutions, Voxelcloud, Vuno, Yitu, Zebra medical vision, and more.

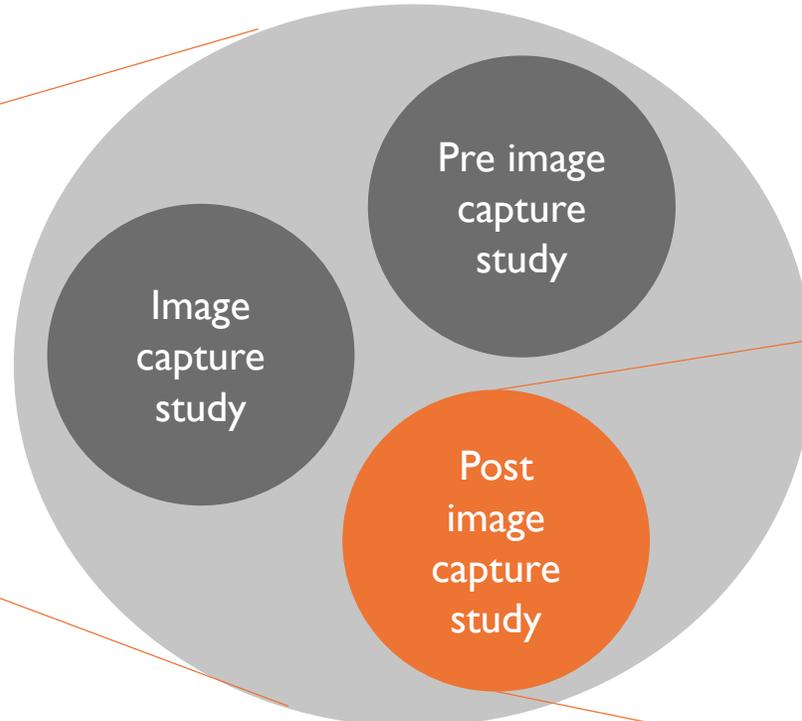
REPORT SCOPE



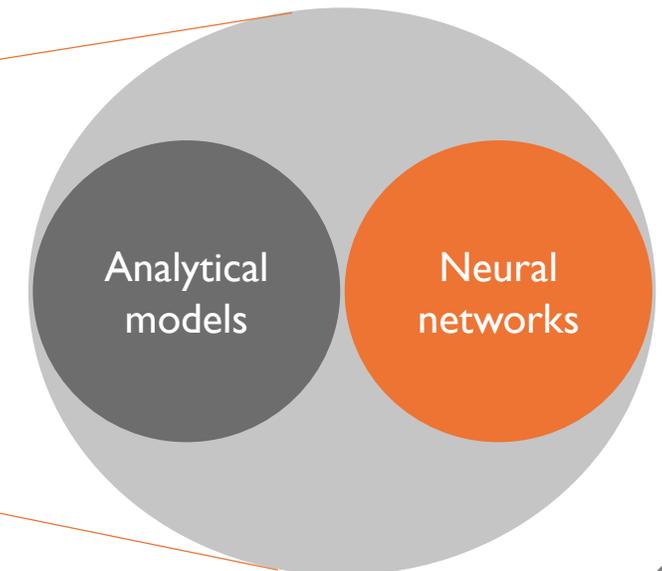
Healthcare



Medical imaging

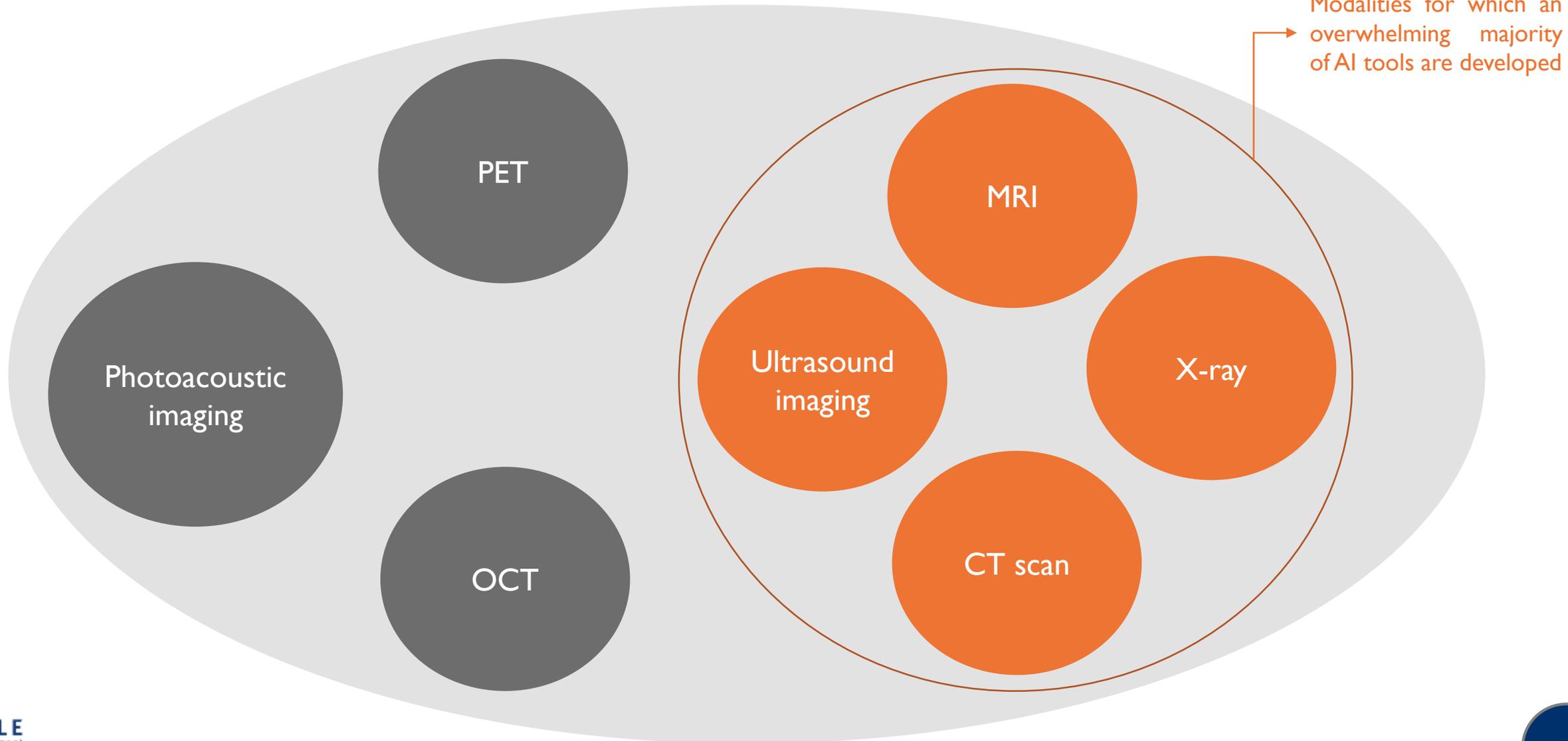


Post image capture study





Medical imaging modalities



Modalities for which an overwhelming majority of AI tools are developed

METHODOLOGIES & DEFINITIONS

Yole Développement's market forecast model is based on the matching of several sources:

Comparison with existing data
Monitoring of corporate communication
Using other market research data
Yole analysis (consensus or not)

Comparison with prior Yole reports
Recursive improvement of dataset
Customer feedback

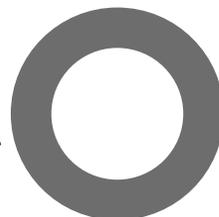
Preexisting information

Top-to-bottom approach
Aggregate of market forecasts
@ System level



Market
Volume (in Munits)
ASP (in \$)
Revenue (in \$M)

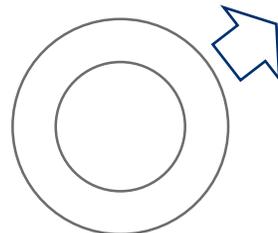
Bottom-up approach
Ecosystem analysis
Aggregate of all players' revenue
@ System level



Primary data

- Reverse costing
- Patent analysis
- Annual reports
- Direct interviews

Top-to-bottom approach
Aggregate of market forecast
@ Semiconductor device level

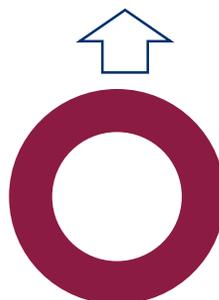


Bottom-up approach
Ecosystem analysis
Aggregate of key players' revenues
@ Semiconductor device level



Secondary data

- Press releases
- Industry organization reports
- Conferences



Semiconductor foundry activity
Capacity investments and equipment needs

Information Aggregation

WHO SHOULD BE INTERESTED IN THIS REPORT?



Regulation agencies:

- Evaluate the market potential of future technologies and products for new applicative markets
- Identify new expectations of every player of the ecosystem
- Evaluate the growth rate of specific market

AI algorithm producer companies:

- Spot new technologies and define diversification strategies
- Position your company in the ecosystem

Insurance and medical companies:

- Understand the strategies of big players and start-ups

Marketplaces and PACS companies:

- Comprehend ecosystem dynamics
- Realize the differentiated value of your products and technologies in this market
- Identify new business opportunities and prospects

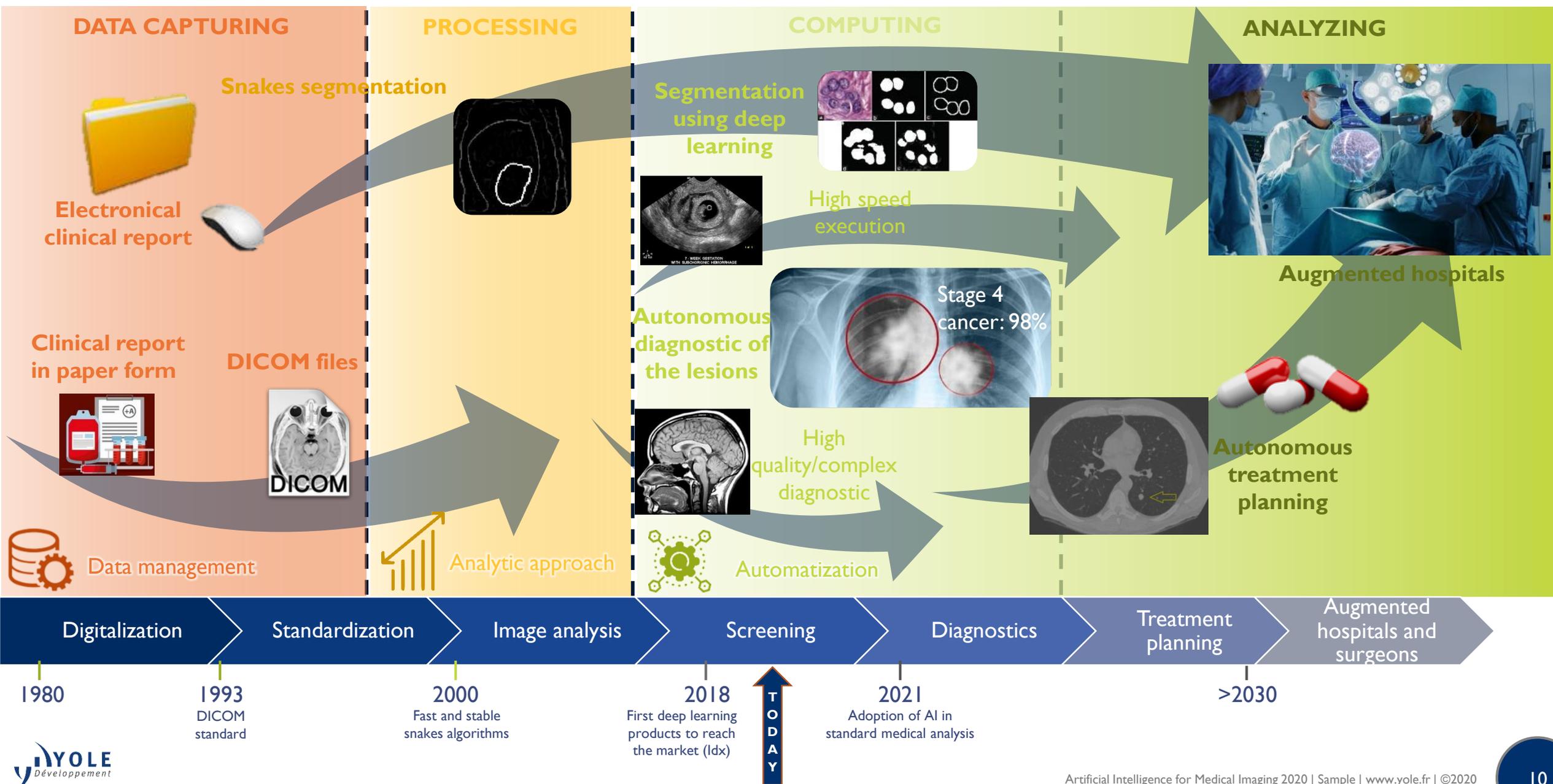
Medical device manufacturers and OEMs:

- Analyze the benefits of using these new technologies in your end-system
- Filter and select new suppliers

Financial and strategic investors:

- Grasp the potential of technologies and markets
- Acquaint yourself with key emerging companies and start-ups

ON THE ROAD TO AUTONOMOUS TREATMENT PLANNING



Machine learning is used to build a mathematical model to make predictions without any explicit conditions.

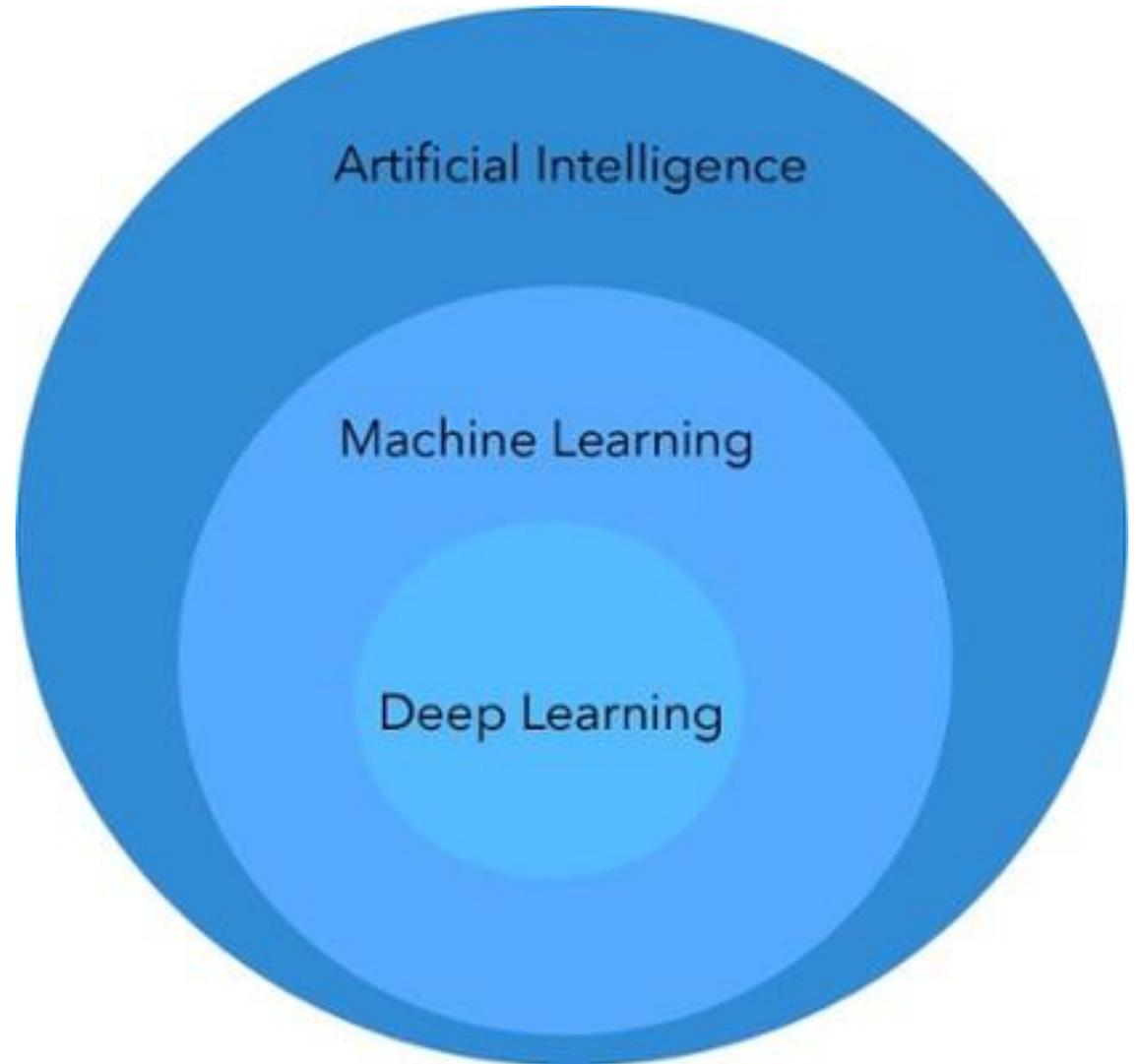
Machine learning is a **statistical model**.

Deep learning is a branch of machine learning and is based on **deep neural networks**.

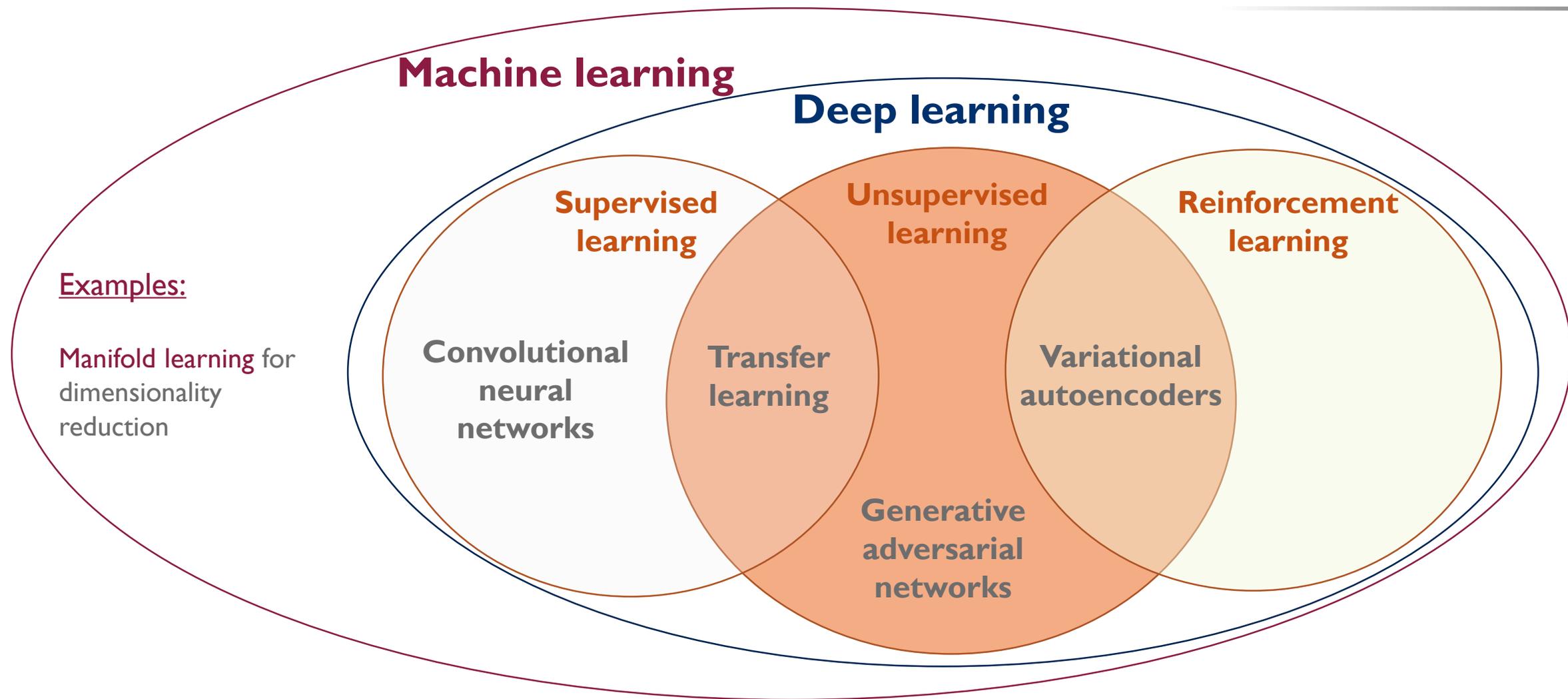
This model is mainly used in computer vision or in audio recognition.

Deep learning models get the best accuracy when applied on recognition which explains why it is used in all algorithms applied to **medical imaging**.

The report is focused on medical imaging. Hence to analyze companies using deep learning algorithms.



MACHINE LEARNING & DEEP LEARNING OVERVIEW



Those algorithms presented are a small part of all the developed models. Even though, in the field of medical imaging, it represents the most accurate ones.

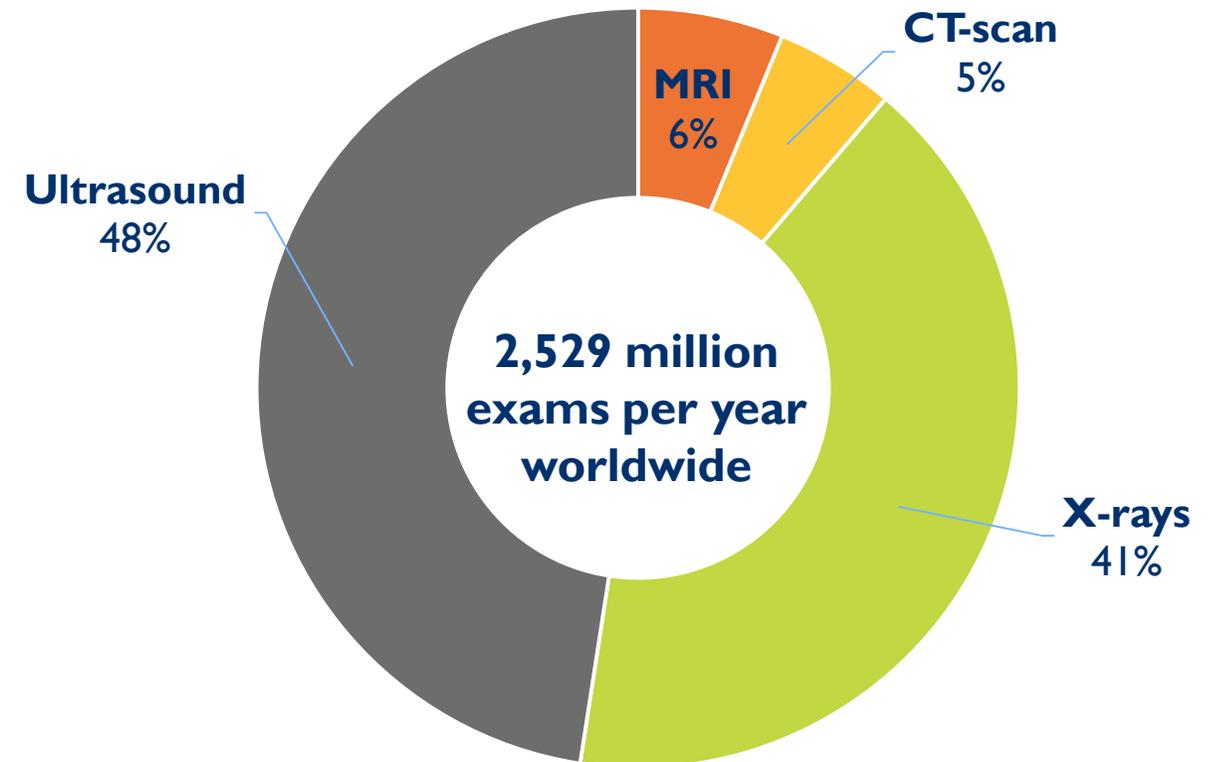


Equivalent to the acquisition of

360* medical exams
every second worldwide.

- Ultrasound images, even though are the most acquired ones, but are not well suited for AI analysis;
- X-rays: Highly accurate deep learning models currently limited by the difficult analysis of low contrast images;
- Deep learning technics are well adapted to MRI and CT-scan corresponding to 11% of total images acquired worldwide in 2018.

Number of exams acquired WW
in million units in 2018
Per modality

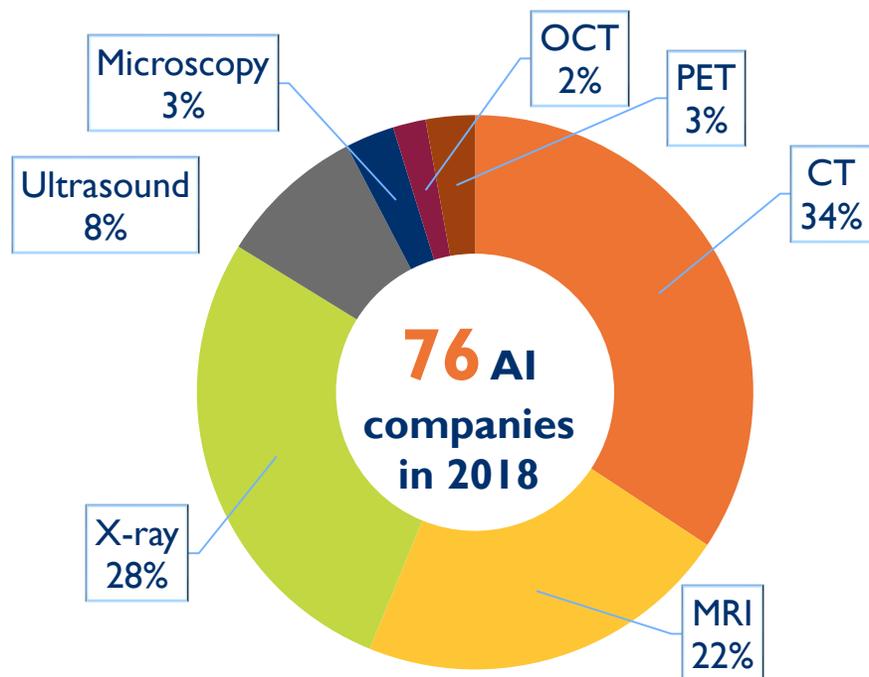


* Based on the average number of working days per year.

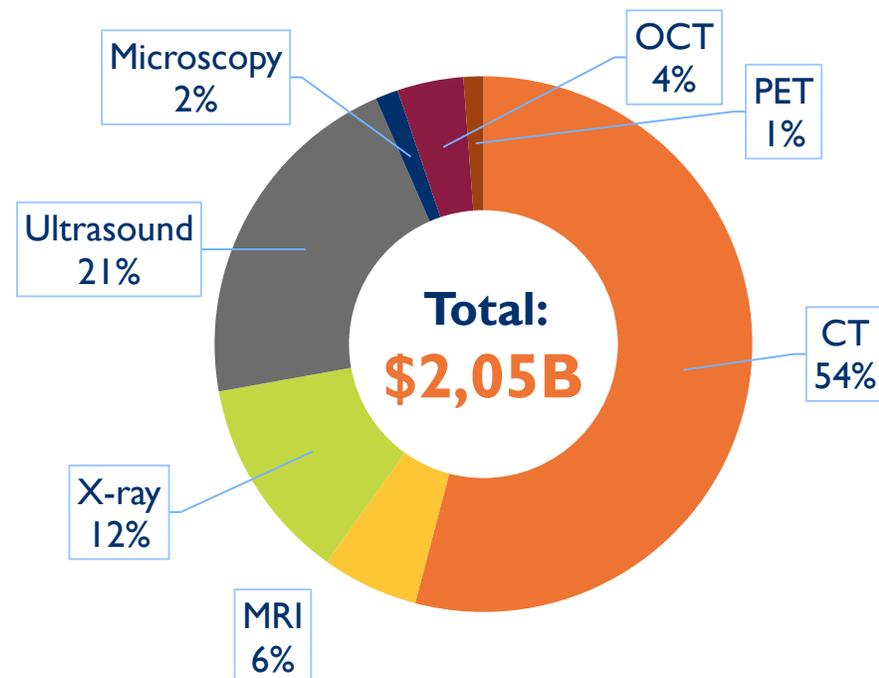
AI COMPANIES: STRONG INVESTMENTS

Where to find the investments?

Percentage of AI company per modality

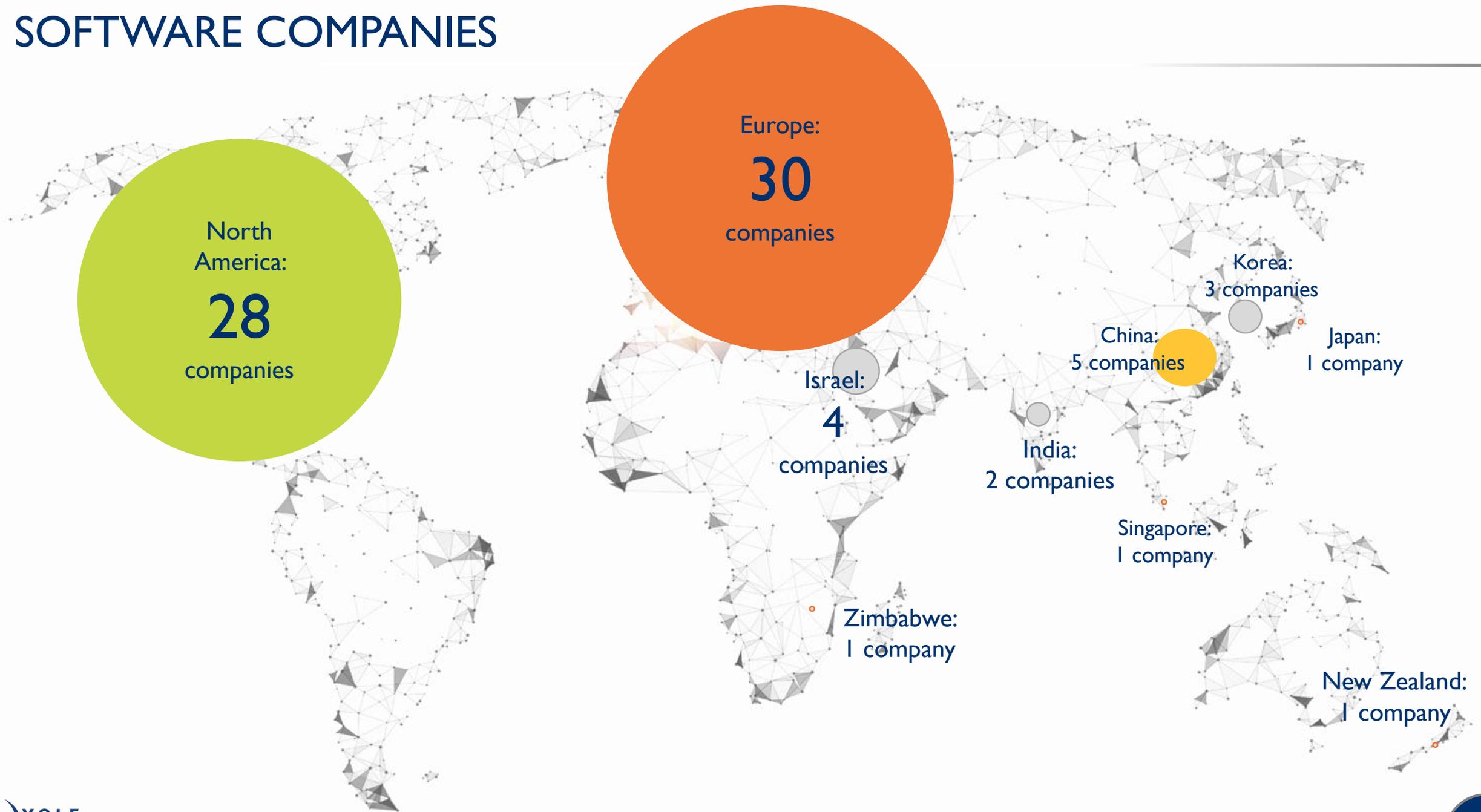


Percentage of investment per modality in AI between 2010 and 2019

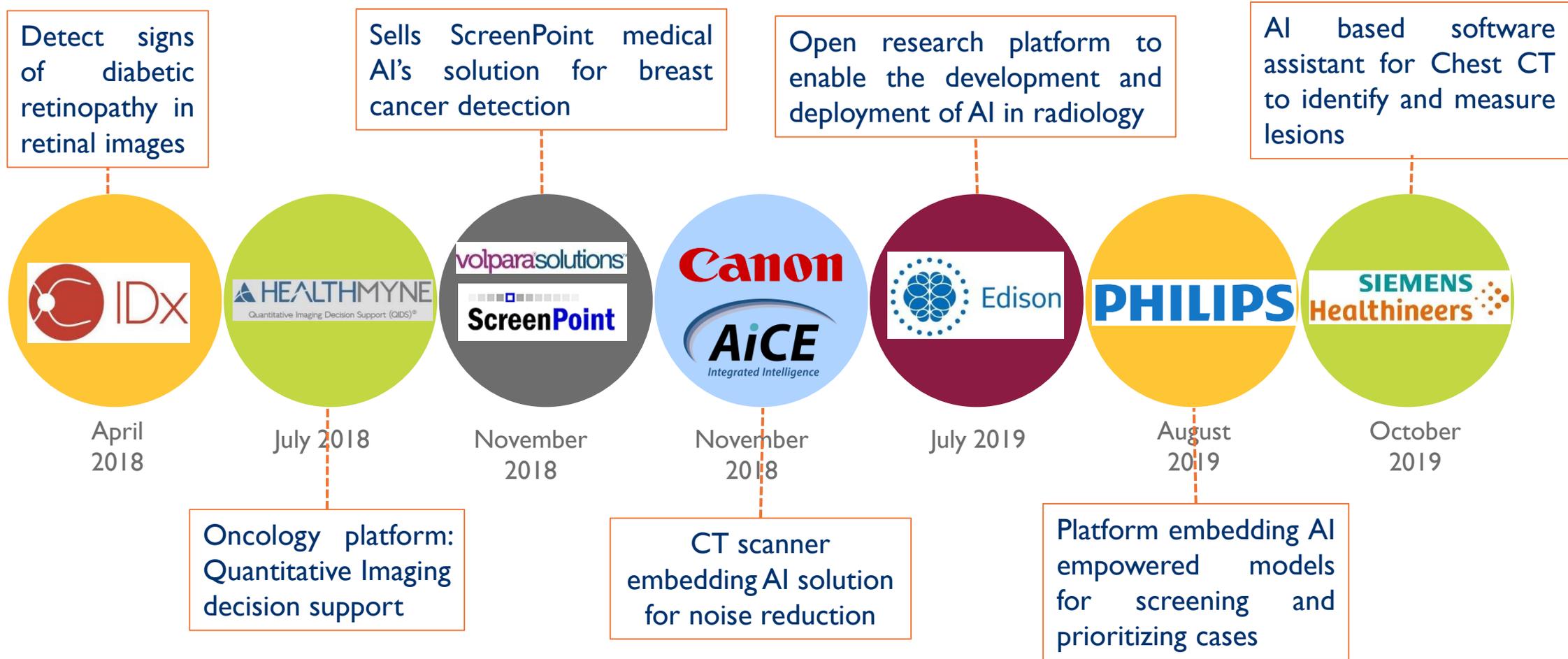


Venture capitals and medical field companies invested in new software companies developing deep learning models. This huge amount of investment highlights the enormous potential of this technology in this particular sector.

SOFTWARE COMPANIES



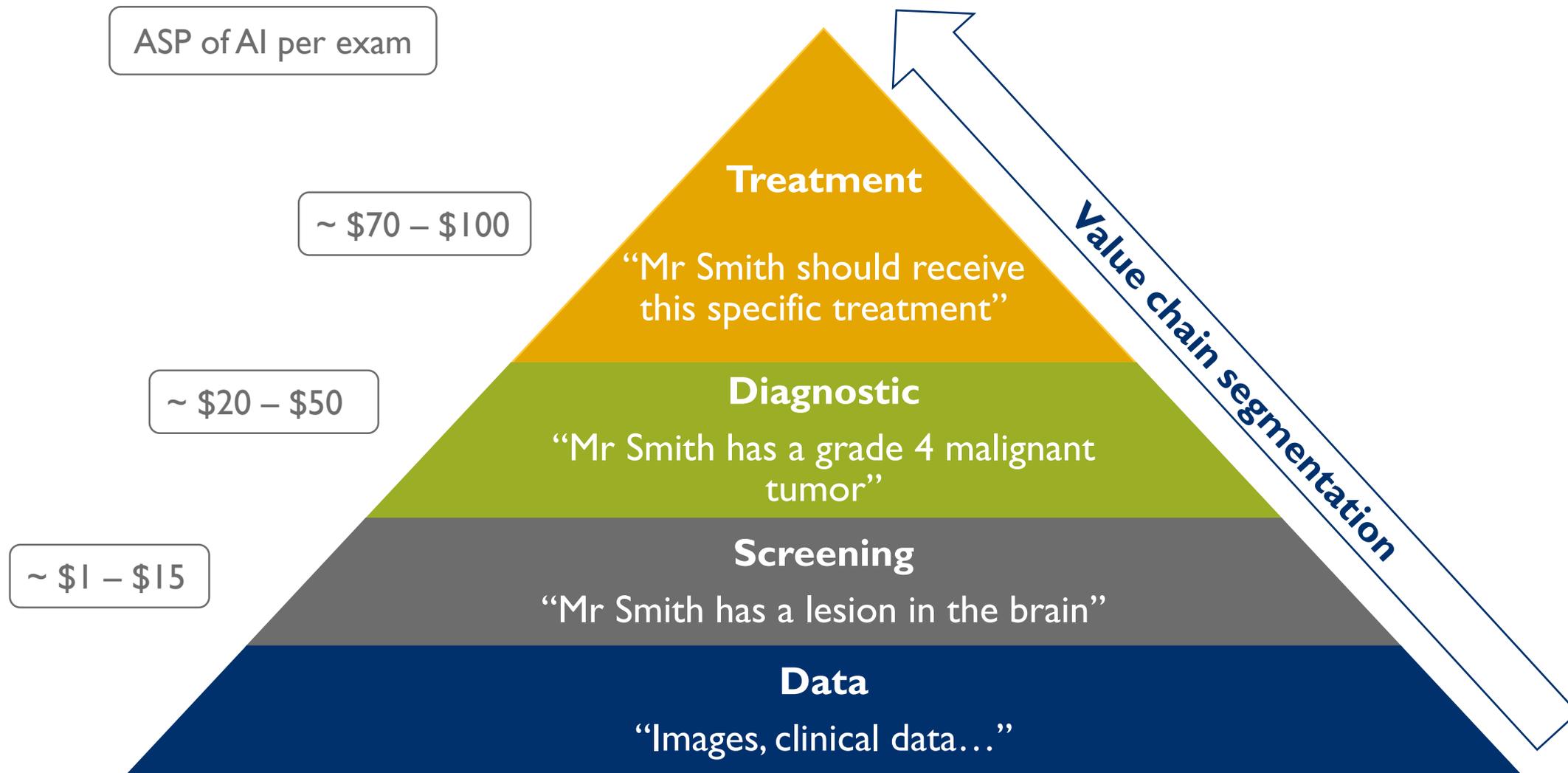
MAIN RELEASES OF AI PRODUCTS ON THE MARKET IN 2018-2019



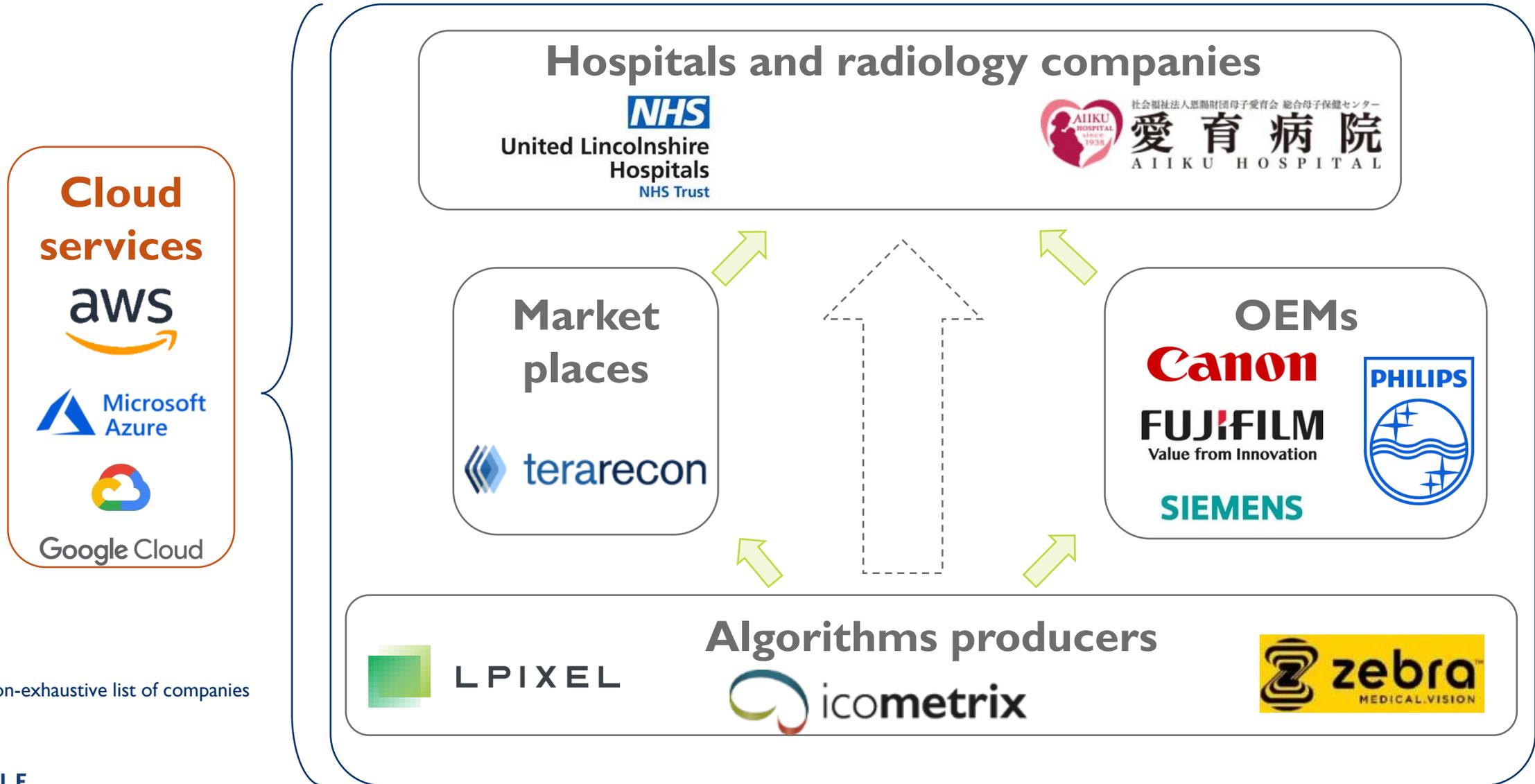
The arrival of OEMs on the AI market will boost the introduction of new tools based on deep learning.

DATA IN HEALTHCARE

The AI algorithm value chain



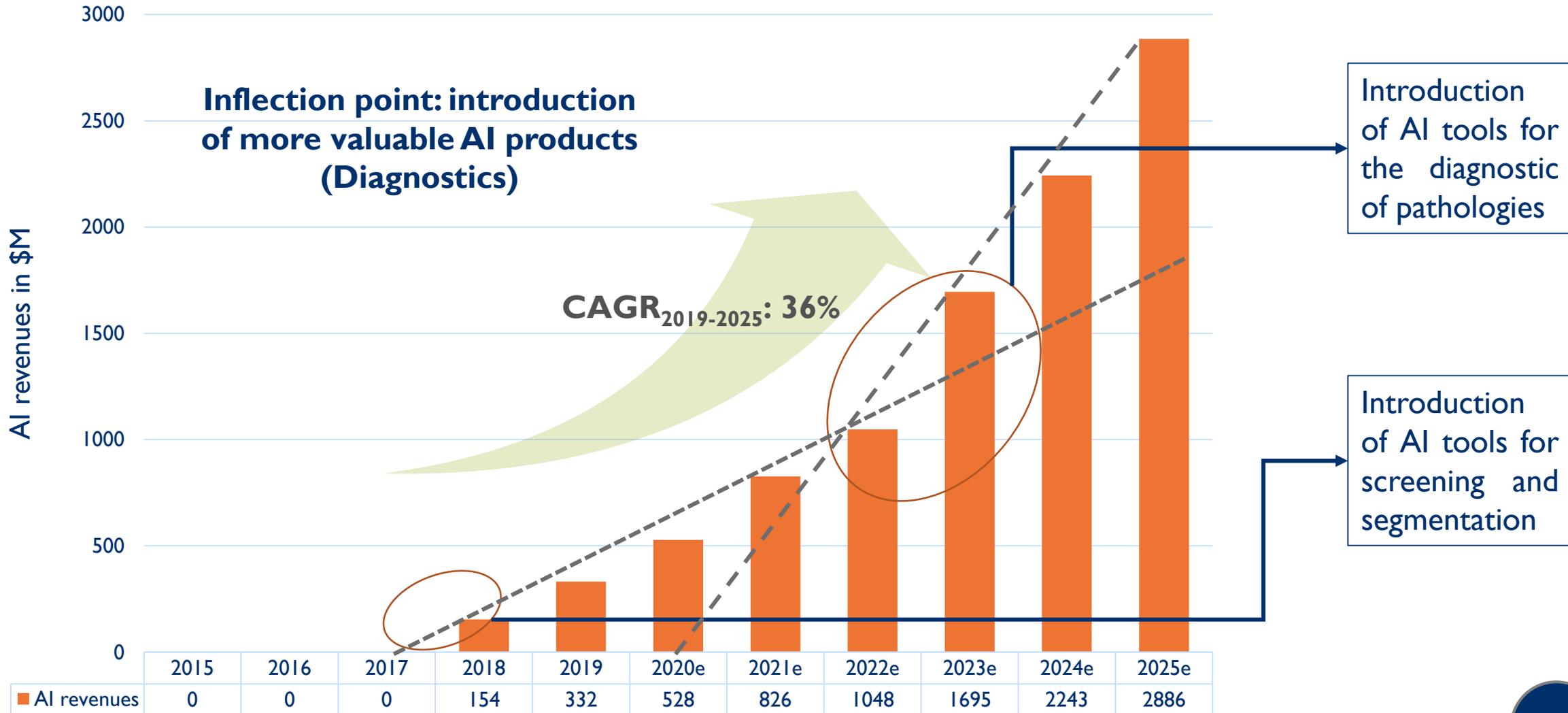
SIMPLIFIED ECOSYSTEM OF PLAYERS ENABLING THE ADOPTION OF AI IN THE MEDICAL FIELD



*Non-exhaustive list of companies

TOTAL AI REVENUES OF AI COMPANIES IN THE MEDICAL IMAGING FIELD

The global evolution forecasts of AI revenues for medical imaging 2015-2025





A GLANCE OF HISTORY

Artificial Intelligence - 1950 to 2019, and beyond

1950 Marron behavior, intelligent behavior

1956 The Dartmouth College AI summer conference

1959 Turing test - first serious proposal as the philosophy of artificial intelligence.

1951 First gene AI: draughts written by Christopher Strachey

2005 Recommendation technology based on tracking web activity

2014 Facebook researchers publish their work on DeepFace, a system that recognizes faces

These days

YOLO Développement

THE WORK OF THE RADIOLOGIST

What are the challenges?

The images available are more and more numerous and complex, in more and more varied contexts: diagnosis, follow-up, screening, treatment planning, evolution prediction, quantification (of lesions, response to treatment...)

The number of radiologists of images to study is growing tasks.

AI is bringing help to radiologists: better accuracy in certain tasks, prioritize patients.

YOLO Développement

DIFFERENT TYPES OF MEDICAL IMAGING

Challenges & differences

	Contrast	Acquisition time	Applications	Signal used	AI improvements	Example
Ultrasound	Depend on the density of water		Echography, blood vessel, muscle	High frequency		
X-rays	Depend on density of organs					
CT scans	Depend on density of organs					
MRI	Depend on presence of water					
PET	Depend on presence of positrons by radiotracer					

YOLO Développement

WHAT ABOUT FUTURE ?

AI related possibilities

Artificial Intelligence and especially deep learning allows more in-depth analysis as well as autonomous screening in the medical and medical imaging field.

Medical images represent a large majority of the global medical data, and due to their enormous number it is possible to develop deep learning algorithms that can analyze this data. For example, a CT scan represents a very large amount of data.

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DEEP LEARNING

Basic description

An easily complete chain of Neural Networks

In a neural network, there are always an input layer, an output layer and a layer in-between called hidden layer. When there are more than 2 hidden layers in a neural network, the algorithm is called **deep learning**.

Deep learning algorithms provides a higher number of hidden layers and are able to process images.

All algorithms processing medical images are deep learning because they are intended to do recognition (machine learning has not been designed to do recognition).

Of course, in many cases, deep learning and machine learning are used to analyze the results of recognition and cross-reference them with other quantitative data.

There are numerous different deep learning algorithms analyzing medical images: Convolutional Neural Network, Variational autoencoder...

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Artificial Intelligence for medical imaging | Report | www.yole.fr | 02019 78

- AI overview
- Medical applications
- Data in healthcare
- What about future?

MARKET FORECASTS

MARKET DATA AND FORECAST: HYPOTHESIS

Which value is evaluated?

The value we have evaluated is the value of AI products. For example, if a CT scanner manufacturer does integrate AI, the value of the product is evaluated.

- Previous M
- Deep learn
- The range simple ima

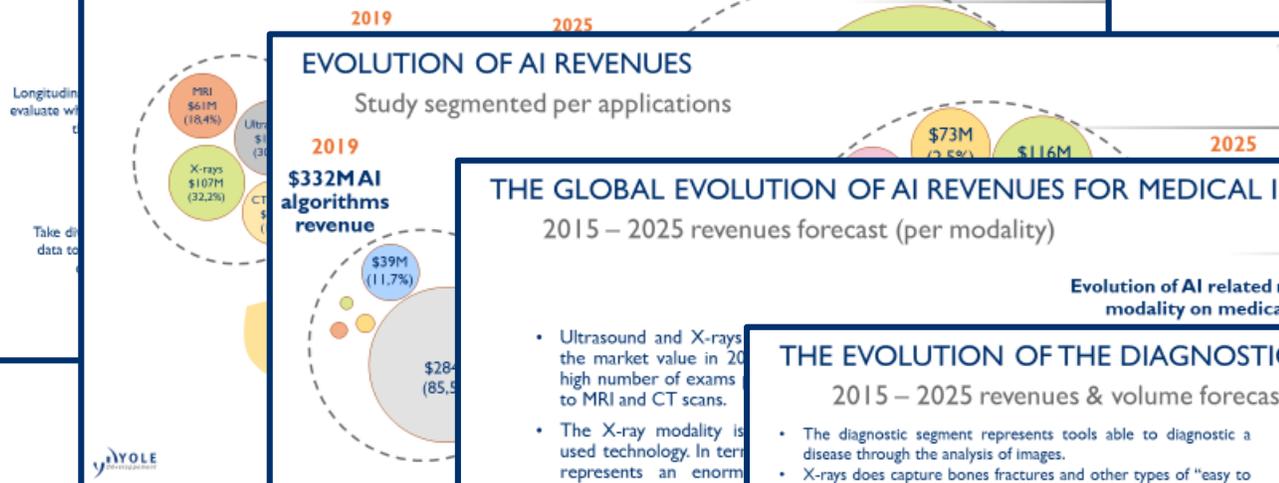
HYPOTHESIS ON PENETRATION RATES

The segmentation used

To b
field

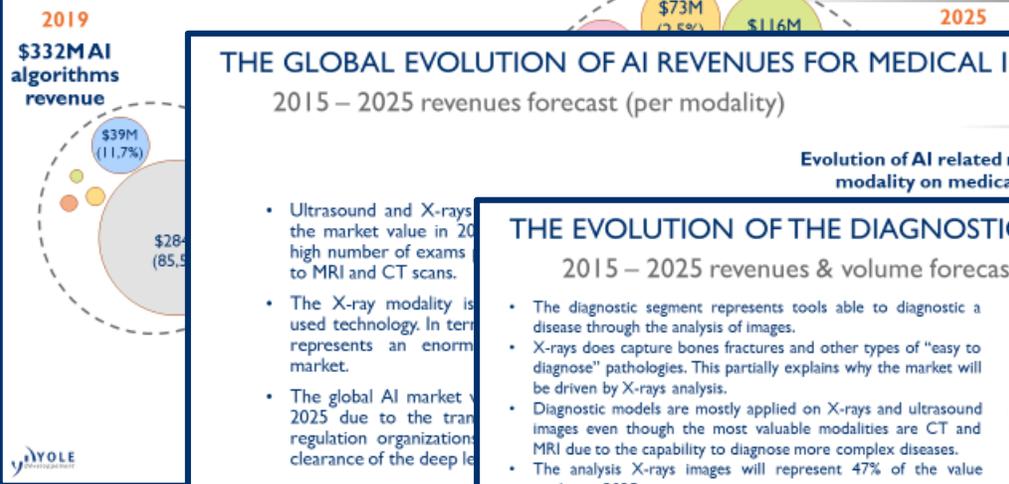
EVOLUTION OF AI REVENUES

Study segmented by modalities



EVOLUTION OF AI REVENUES

Study segmented per applications



THE GLOBAL EVOLUTION OF AI REVENUES FOR MEDICAL IMAGING

2015 – 2025 revenues forecast (per modality)

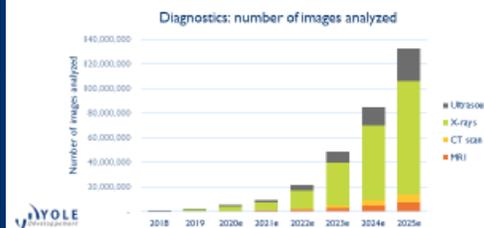
Evolution of AI related revenues per modality on medical images

- Ultrasound and X-rays are the market value in 2025 due to the high number of exams to MRI and CT scans.
- The X-ray modality is used technology. In terms of volume, it represents an enormous market.
- The global AI market in 2025 due to the transition of regulatory organizations and the clearance of the deep learning.

THE EVOLUTION OF THE DIAGNOSTIC SEGMENT AI REVENUE

2015 – 2025 revenues & volume forecast (per modality)

- The diagnostic segment represents tools able to diagnose a disease through the analysis of images.
- X-rays does capture bones fractures and other types of "easy to diagnose" pathologies. This partially explains why the market will be driven by X-rays analysis.
- Diagnostic models are mostly applied on X-rays and ultrasound images even though the most valuable modalities are CT and MRI due to the capability to diagnose more complex diseases.
- The analysis X-rays images will represent 47% of the value market in 2025.



Evolution of AI related revenues for the diagnostic on medical images



	2015	2016	2017	2018	2019	2020e	2021e	2022e	2023e	2024e	2025e	CAGR
Ultrasound	0	0	0	2	11	39	76	140	257	478	875	52%
X-rays	0	0	0	5	18	51	84	133	211	330	575	64%
CT scan	0	0	0	2	3	4	15	31	65	141	311	82%
MRI	0	0	0	2	7	11	26	47	86	156	330	67%
Total	0	0	0	12	39	84	130	231	519	788	1216	63%

- Assumptions on penetration rates and ASP
- Total AI revenue
- Evolution by application
- Evolution by modality
- Evolution of AI revenues per segment



Medical data are still interesting for marketing use.

The market is not mature enough to evaluate the most profitable business models.

Teleradiology is an interesting solution to manage medical data.

The integration of AI can easily be performed when using cloud technologies.

The integration of AI can easily be performed when using cloud technologies.

OEMs will benefit a lot from AI in 10 years by using enhanced low quality sensors.

THE DATA MARKET

The strategy of major players to get data

BUSINESS MODELS OF SOFTWARE PRODUCER: A COMPLEX STRATEGY

The need for visibility

THE DATA MANAGEMENT FOR HOMOGENEOUS DATABASE

Teleradiology

PACS (PICTURE ARCHIVING AND COMMUNICATION SYSTEM)

The integration of AI modules.

THE EXAMPLE OF AN MRI EXAM

Proportion of the technical and intellectual package

WHICH REGULATIONS ARE CONSTRAINTS FOR AI AND WHICH ARE NOT ?

A supervised introduction of AI on the market

INSURANCE COMPANIES

The integration of AI into the reimbursement system

IMPACT OF AI: ROAD TO LOW COSTS/LOW QUALITY SENSORS

How AI is changing the way data is processed?

Different types of AI algorithms improve images: **Preprocessing tools and post processing tools.**

Preprocessing: Algorithms applied on the raw data (not applied on images) → currently at a research phase.

Post processing: Algorithms applied on images. The noise reduction represents a large part of the enhancement AI could bring to medical devices → this is the case on CT scanner and Ultrasound imaging device.

The possibility to improve the resolution, the noise presence and the sensitivity of an image enable **medical device manufacturers to use low quality sensors** acquiring low quality images greatly enhanced by AI tools.

Such models are currently at a research phase due to difficult implementation of reconstruction models → **can we trust fully AI-reconstructed images ?**

Ultrasound probe based on PZT
source: NDK

- AI for medical imaging: a software business
- Insurance benefits
- The regulations and constraints
- What's next



- Why using AI
- Modality specifics
- Software development
- IT infrastructure

MRI IMAGING: HIGH QUALITY IMAGING

MRI images are the most accurate ones on the market allowing the training and the deployment of the most accurate deep learning models.

The post acquisition treatment planning is the most common application, though, other applications are emerging.

- Faster acquisition
- Use of lower energy
- This would allow for a wider distribution (currently distributed in high-end centers)

Currently existing solutions:

- Stabilization and denoising
- Patient slight motion correction
- Widely spread in clinical practice

CT SCANS IMAGING: THE CURRENT FOCUS OF OEM

The most targeted modality for the use of AI models is currently the CT scanner.

Indeed, in the US, the development of AI models for CT is the most active.

It allows the development of new models.

Nevertheless, some challenges remain:

- Possibility to perform reconstruction
- Develop radiomics for reconstruction
- A faster acquisition
- CT spectral scan allowing more information

Current products:

- AiCE Canon
- Radiation dose reduction

ULTRASOUND: THE AI INTEGRATION FOR NOISE REDUCTION

The most valuable modality

- Siemens has filed numerous patents for AI.
- The number of ultrasound machines is increasing.
- Different uses of AI:
 - Row data analysis: sensitivity of this modality
 - Post acquisition: Image enhancement
- By combining those 2 approaches, it allows for more accurate analyses in the case of a patient.
- A low price device will be developed.

The AI models are relying on the quality of the images and annotations.

In terms of value, they perform fast and accurately.

DEVELOPMENT RESOURCES / PARAMETRIZATION RESOURCES

Current development trends

Differences:

- The number of machines
- Clinical applications
- The number of machines
- The number of machines
- The number of machines

The quality of the data is a determining factor.

The new solutions proposed by cloud companies are improving data security.

ON PREMISE COMPUTING

An interesting solution for hospitals

Particularities:

- Give more control
- Give more control
- Do not require high speed diagnosis
- Need for high speed diagnosis

Cloud computing:

Embedded AI could become more common in some specific situations.

MEDICAL IMAGING: CLOUD OR ON THE EDGE?

The future of medical imaging 2/2

Acquisition time (min)	PET/CT: 5 mm sphere	PET/MR: 5 mm sphere	PET/CT: 4 mm sphere	PET/MR: 4 mm sphere
0	2.5	2.5	2.5	2.5
2	3.5	3.5	3.5	3.5
4	4.5	4.5	4.5	4.5
6	5.5	5.5	5.5	5.5
8	6.5	6.5	6.5	6.5
10	7.5	7.5	7.5	7.5

Current cloud infrastructure:

- Execution speed does not slow the radiologist's workflow in most of the cases.
- The security of the data has been fairly regulated by the global community.
- CT, MRI does not require very high speed diagnosis since the machine captures patient's images throughout a long period.

In the following years:

- Development of cloud structures
- Use of edge solutions for data security reasons.
- Embedded AI algorithms will be developed for very high speed modalities such as ultrasound.

Cloud and on premise computing are preferred by hospitals to embedded hardware for costs reasons.

YOLE GROUP OF COMPANIES RELATED REPORTS

Yole Développement

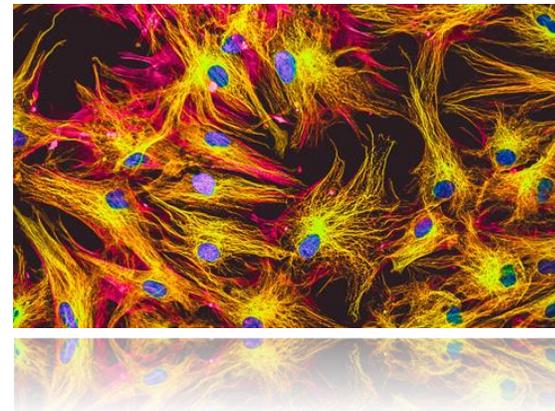
X-Ray Detectors for Medical,
Industrial and Security
Applications 2019



Artificial Intelligence
Computing for Consumer 2019



Cameras for Microscopy and
Next-Generation Sequencing
2019



Artificial Intelligence
Computing for Automotive
2019



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Artificial Intelligence in Medical Diagnostics – Patent landscape analysis 2019



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