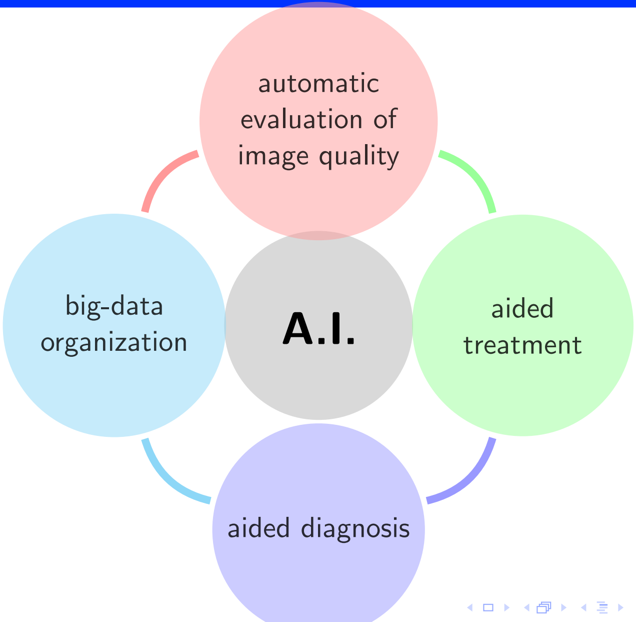
Florence Workshop:
"Artificial Intelligence For Physical Science"
(AI4PHYS)

Physics for Medicine

29/01/2025

Sandra Doria

Artificial Intelligence in medicine



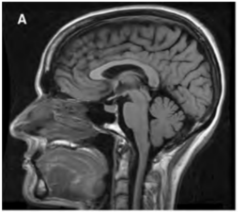
Medical imaging modalities

- Computer Vision algorithms have important applications in medical imaging

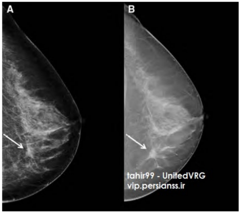
Nuclear Medicine

Ultrasound imaging

Magnetic resonance



X-ray imaging



Development of (X-ray) medical imaging

German physics professor Conrad Roengten

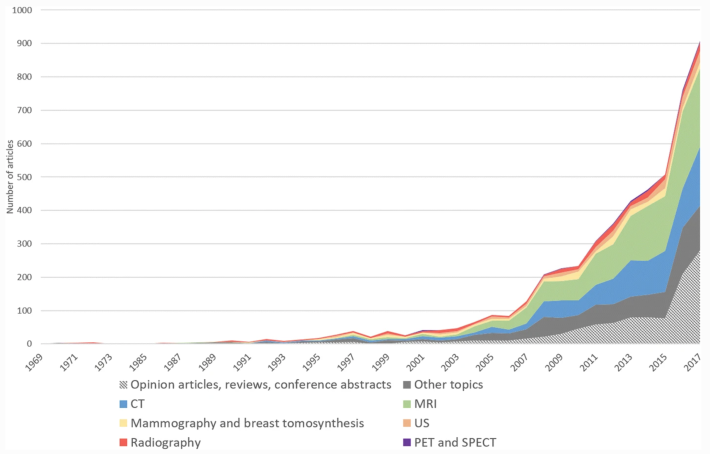
Hand of Anna Bertha Ludwig (1895)

Today

- Understanding of human body

- Computer technology/networking (images sharing among sites)
- Massive amounts of information about patients
- Technology advancements, equipment and digital images

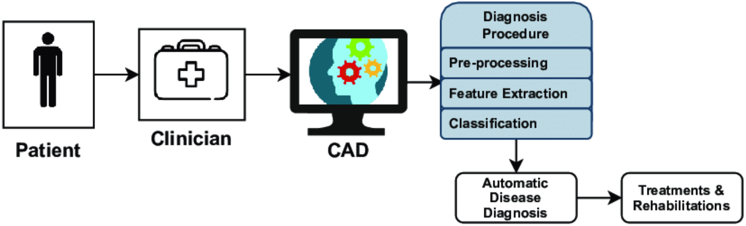
AI in medical imaging



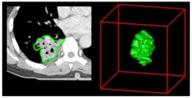
Pesapane *et al. European Radiology Experimental* (2018) 2:35
https://doi.org/10.1186/s41747-018-0061-6

CNN in medical imaging

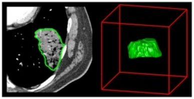
- **Computed Aided Diagnosis** (CAD): uses a computer program to detect features likely to be of clinical significance in images.



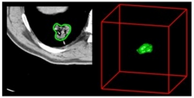
- **Radiomics** uses descriptors aiming to find associations between qualitative and quantitative informations extracted from clinical images and clinical data



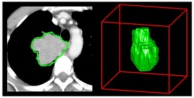
Standard deviation: 208.9
Shape sphericity: 0.46
Texture RLGL nonuniformity: 3,622.3
LoG entropy: 3.89



Standard deviation: 116.0
Shape sphericity: 0.62
Texture RLGL nonuniformity: 5,276.5
LoG entropy: 3.44



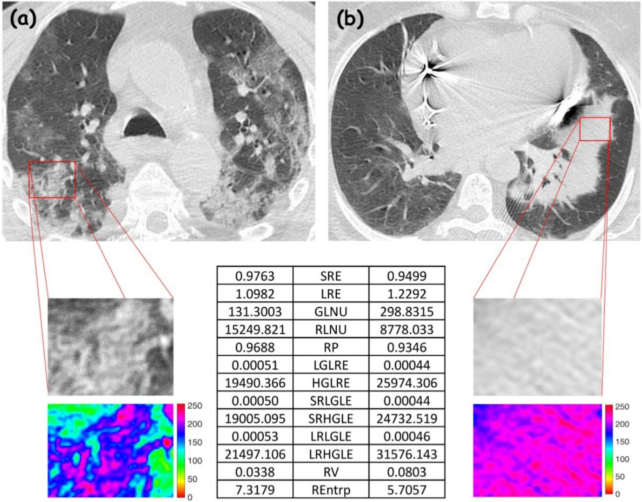
Standard deviation: 133.2
Shape sphericity: 0.669
Texture RLGL nonuniformity: 265.1
LoG entropy: 3.93



Standard deviation: 80.0
Shape sphericity: 0.65
Texture RLGL nonuniformity: 9,339.6
LoG entropy: 3.04

- Radiomic features exhibit different levels of complexity and express properties of: lesion shape, voxel intensity histogram, intensity spatial arrangement (texture)

Radiomic examples: pneumonia detection

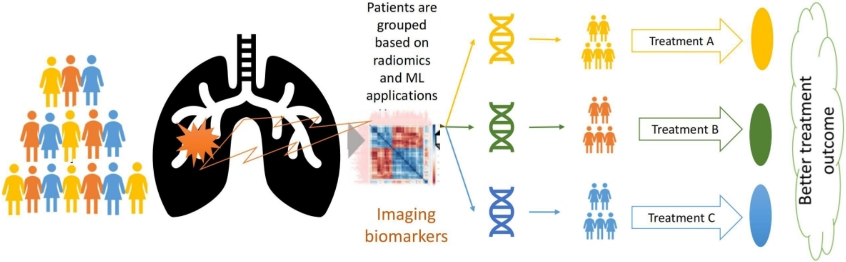


0.9763	SRE	0.9499
1.0982	LRE	1.2292
131.3003	GLNU	298.8315
15249.821	RLNU	8778.033
0.9688	RP	0.9346
0.00051	LGLRE	0.00044
19490.366	HGLRE	25974.306
0.00050	SRLGLE	0.00044
19005.095	SRHGLE	24732.519
0.00053	LRLGLE	0.00046
21497.106	LRHGLE	31576.143
0.0338	RV	0.0803
7.3179	REntrp	5.7057

Fig. 7. HRCT images of patient with COVID-19 (a), non-COVID-19 pneumonia and their corresponding GLRLM features.

Why radiomics?

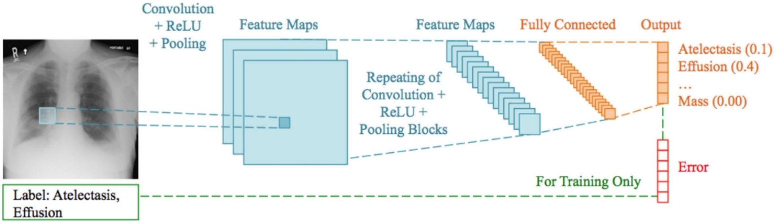
- The goal is to find biomarkers for specific treatment / pathology (e.g. features indicators of tumor aggressiveness)
- Big limitation: standardization of radiomic features across hospitals, protocols, acquisition settings, image processing... Still not overcomed!



- Radiomics was used as a pre-processing step for ML algorithms → Current ML algorithms are powerfull enough to learn directly from images

CNN in medical imaging

- CNNs are the preferred neural networks in image processing because of their ability to maintain spatial information (segmentation, localization etc.)

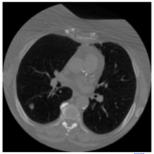


- **Feature extractions**: identifying textures (edges, pixel intensity spatial distributions, spatial periodicity)

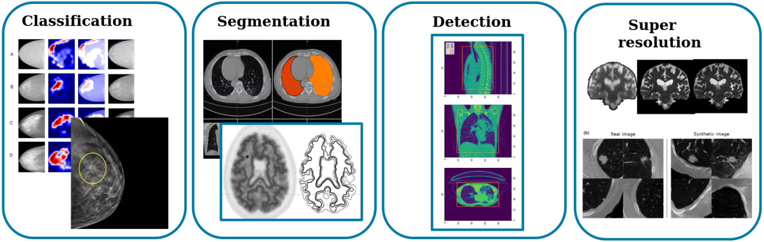
↓

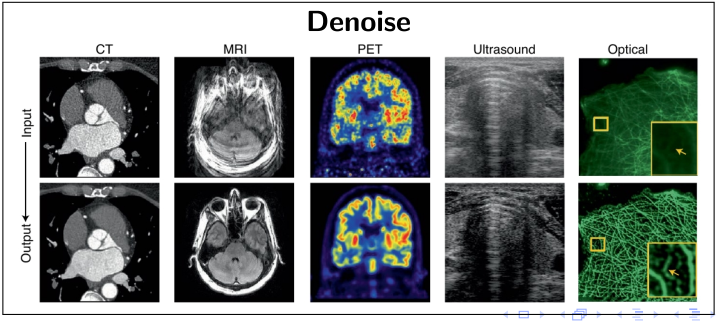
Example: detecting edges with the **Sobel filter**

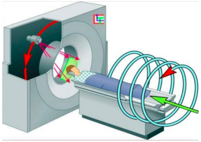
-1	0	-1
-2	0	2
-1	0	1

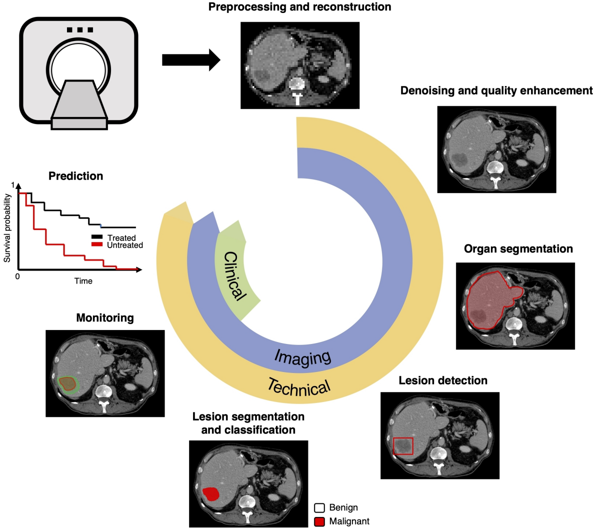


AI in medical imaging: applications



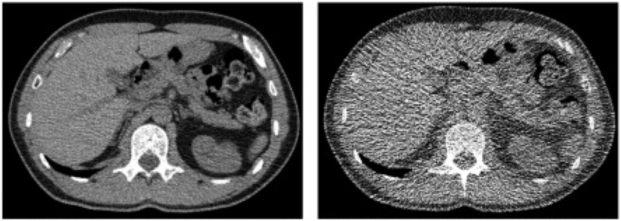





Preprocessing and reconstruction
Denoising and quality enhancement
Organ segmentation
Lesion detection
Lesion segmentation
and classification
Benign
Malignant
Monitoring
Prediction
Survival probability
1
0
Time
Treated
Untreated
Clinical
Imaging
Technical

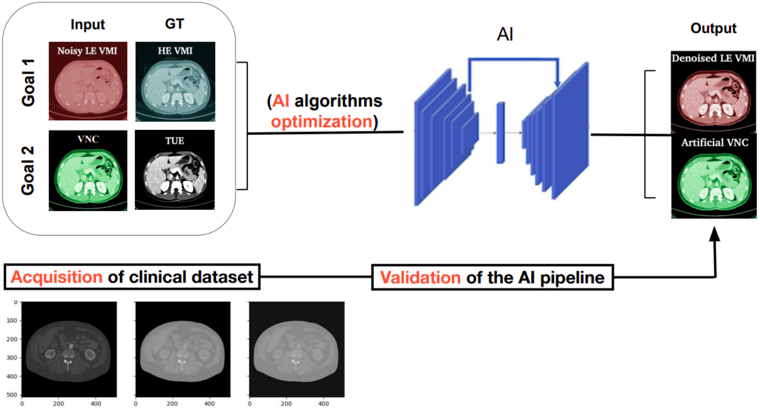
Application: Image Quality enhancement in CT

- Quality enhancement is particulary important in Computed Tomography (and in general x-ray applications) because there is a compromise between radiation dose and noise.



- Increase interest in algorithms for image quality evaluation and enhancement

Research line: Dual Energy Computed Tomography



Dipartimento di Fisica e Astronomia

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CNR iCCOM

FONDAZIONE BRUNO KESSLER

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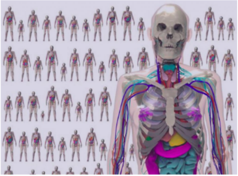
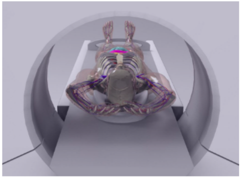
CENTER FOR VIRTUAL IMAGING TRIALS

Last frontier: Virtual Patients



TR&D 1 - Virtual Patients

We are developing a framework from which researchers can generate vast populations of realistic, customizable virtual subjects for 3D and 4D research, significantly advancing human modeling to enable virtual imaging trials.

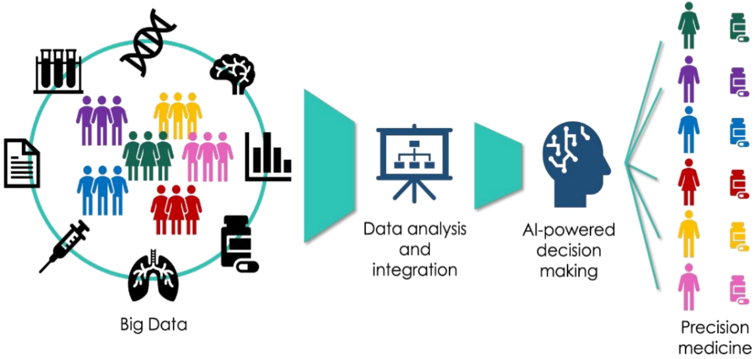


TR&D 2 - Virtual Scanners

We are developing a platform for rapid, accurate, and realistic CT simulations capable of generating 3D and 4D CT images and radiation dose estimates for highly detailed patient-specific anatomies with physiological and perfusion dynamics.

- Virtual datasets represent a powerfull method to generate synthetic realistic data to optimize deep leagning algorithms for medical imaging

Last frontier: Multimodal analysis



- Multimodal analysis are the future challenge of DL in medicine

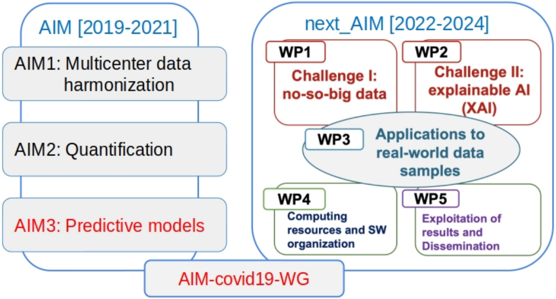
Previous projects @ INFN

INFN-FLORENCE GROUP

C. Talamonti
L. Ubaldi
S. Pallotta
L. Marrazzo
D. Greto
M. Loi
(S. Piffer
M. Berrettini)

Artificial Intelligence to become the next revolution in **medical diagnostics** and **therapy**.

- New image processing and data analysis strategies, including radiom approaches, need to be developed and extensively validated.



Resp. Naz.: A. Retico

14 Research Units:
Bari (S. Tangaro)
Bologna (D. Remondini)
Cagliari (P. Oliva)
Catania (M. Marrale)
Ferrara (G. Paternò)
Firenze (C. Talamonti)
Genova (A. Chincarini)
Lab. Naz. Sud (G. Russo)
Lecce (G. De Nunzio)
Milano (C. Lenardi)
Napoli (G. Mettivier)
Pavia (A. Lascialfari)
Padova (A. Zucchetta)
Pisa (M.E. Fantacci)

Researchers from INFN divisions and University Departments collaborate closely with Clinicians and Medical Physicists of many Italian hospitals and IRCCS, and with international consortia sharing data

Resp. Naz.: A. Retico

12 Research Units:

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INFN 2

Artificial Intelligence in Medicine: focus on Multi-Input Analysis (AIM_MIA)

2025-2017

General goal: *to take a step forward in the development and validation of AI-based tools for medical data analysis*

Objectives

1. Mining multi-modal information
2. Handling incomplete/missing/limited datasets
3. Development of a dedicated data and computing platform