Attività basate su Intelligenza Artificiale (AI) per applicazioni Mediche

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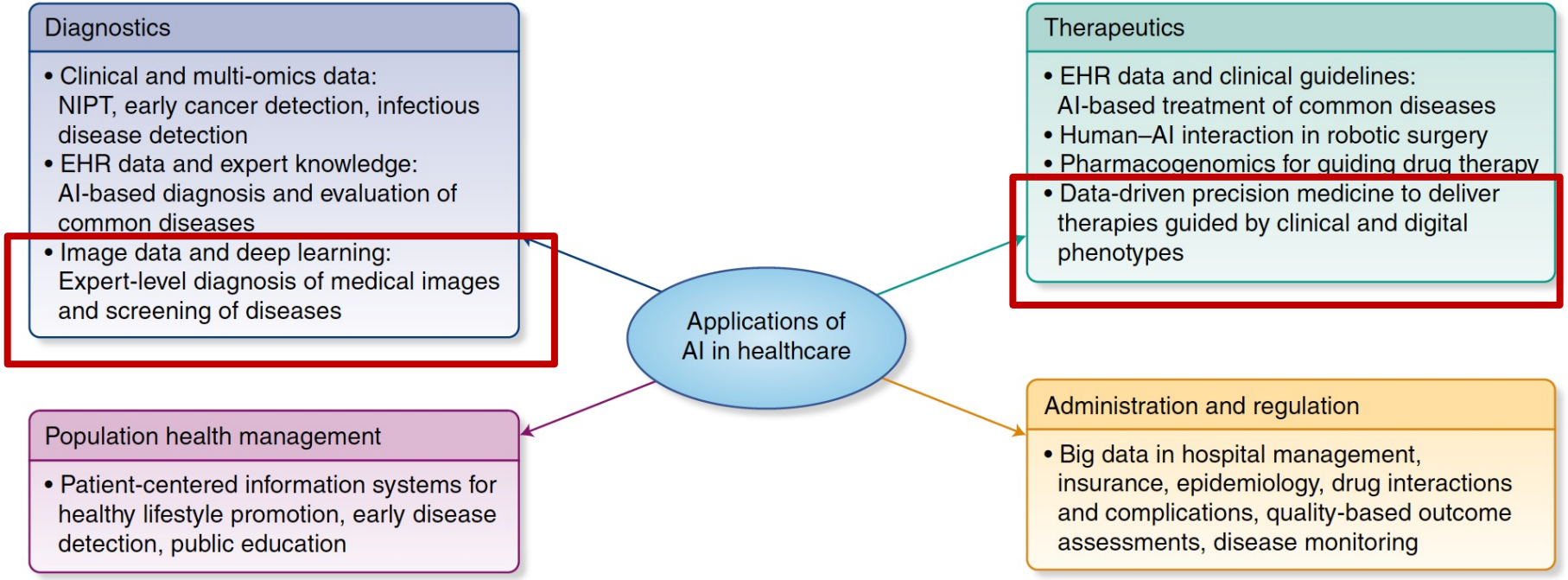
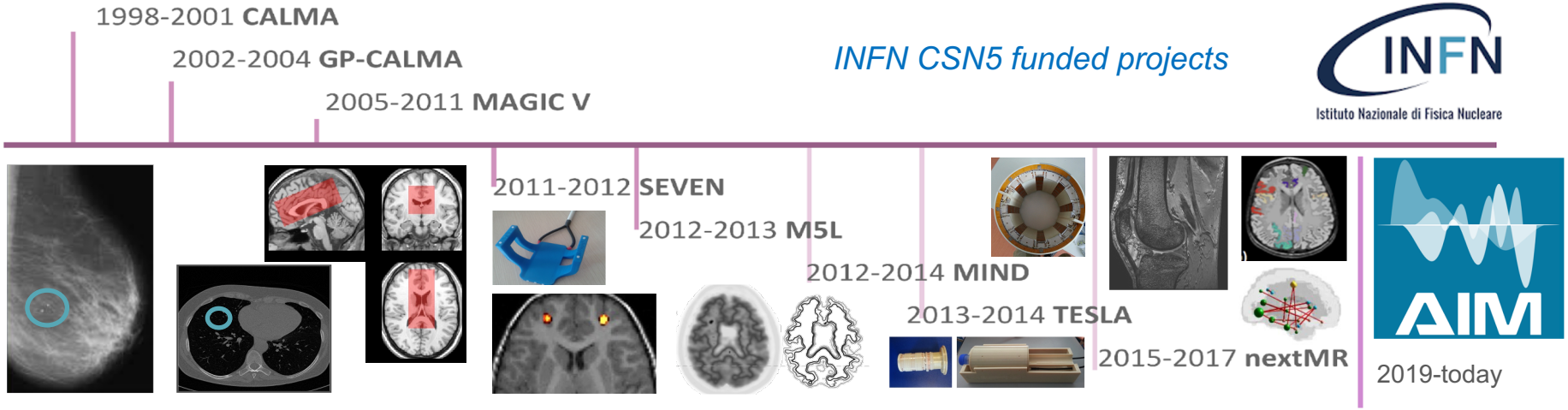
Applicazioni dell'Intelligenza Artificiale (AI) in ambito sanitario



Legend: HER, Electronic Health Records; NIPT, noninvasive prenatal test

J He et al., The practical implementation of artificial intelligence technologies in medicine, Nature Medicine ***25****, 30–36 (2019)*

L'impegno INFN nell'analisi delle immagini mediche

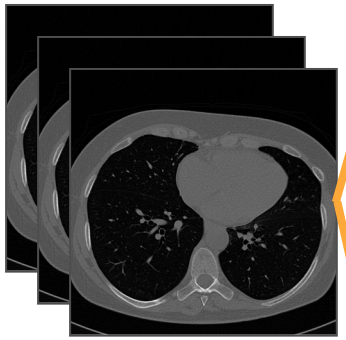


Historical overview of developments in the field of automated diagnosis

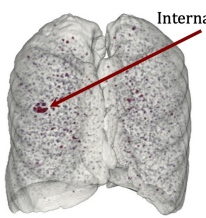
- '90 - Old-fashion systems (rule-based)
  - 2000-today - Hand-crafted feature and Machine Learning classification (Radiomics and ML)
    - since 2016 – Deep-Learning based image classification

Selection of success stories: Lung nodule detection

MAGIC-5 and ML5
INFN projects
[2005-2010]

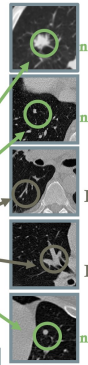


- Enhancement of spherical objects and suppression of elongated and planar structures
  [Li Q, Sone S, Doi K. *Med Phys* (2003)]
- Multi-scale dot-enhancer (MSDE) filter



Search for local maxima → List of internal nodule candidates

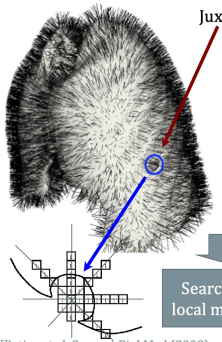
59:293:226:5.0:0:peak1
54:308:213:5.0:0:peak2
175:251:215:5.0:0:peak3
363:249:142:5.0:0:peak4
50:252:243:5.0:0:peak5
323:175:173:5.0:0:peak6
371:150:128:5.0:0:peak7
…
…

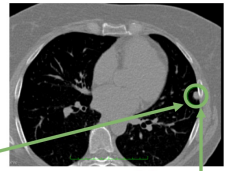


[Retico et al. Comput Biol Med (2008); Camarlinghi et al. Nuovo Cimento (2011)]

The list can contain many false positives

- Enhancement of regions with extra curvature trough a gradient-based filter
  [Paik *et al.* IEEE Trans Med Imaging (2004)]
- Pleura Surface Normal (PSN) filter





Search for local maxima → List of juxta-pleural nodule candidates

59:293:226:5.0:0:peak1
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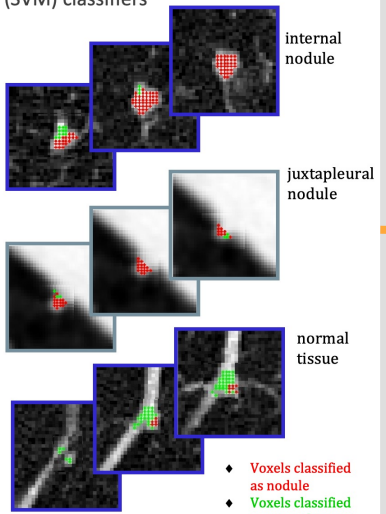
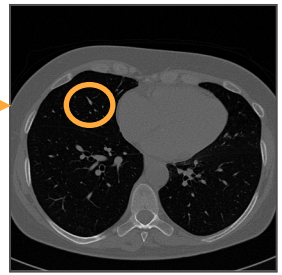
175:251:215:5.0:0:peak3
363:249:142:5.0:0:peak4
50:252:243:5.0:0:peak5
323:175:173:5.0:0:peak6
371:150:128:5.0:0:peak7
…
…

[Retico et al. Comput Biol Med (2009); Camarlinghi et al. Nuovo Cimento (2011)]

The list can contain many false positives

Voxel-wise classification of candidate nodules with Support Vector Machines (SVM) classifiers





Sviluppato in collaborazione con:
- AOUP (Dott. Falaschi) e Univ. di Pisa (Prof D. Caramella)
- Bracco Imaging S.p. A.

Selection of success stories: Lung nodule detection

- Lung nodule detection SW developed by INFN MAGIC-5 and M5L projects

  → laboratory performance: 80% sensitivity to nodules @ 5 PF/exam

  → clinical validation

Assisted reading improves nodule detection by +7% in the per-patient analysis

MAGIC-5 and M5L project leader: PG. Cerello

Collaboration with. D. Regge, Candiolo Cancer Institute-FPO, IRCCS and Univ. of Turin

European Radiology
https://doi.org/10.1007/s00330-018-5528-6

COMPUTER APPLICATIONS

CrossMark

A cloud-based computer-aided detection system improves identification of lung nodules on computed tomography scans of patients with extra-thoracic malignancies

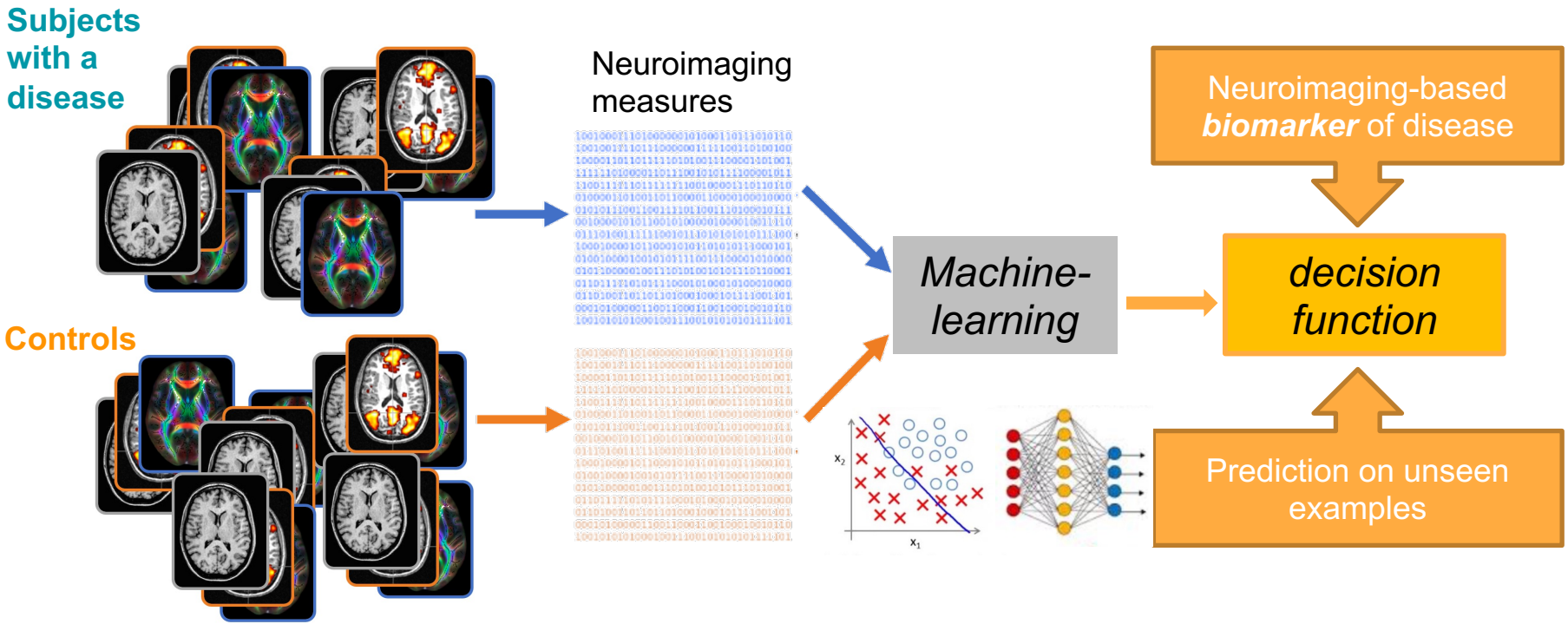
Lorenzo Vassallo[1,2] · Alberto Traverso[3,4] · Michelangelo Agnello[3] · Christian Bracco[5] · Delia Campanella[1] · Gabriele Chiara[1] · Maria Evelina Fantacci[6] · Ernesto Lopez Torres[7] · Antonio Manca[1] · Marco Saletta[7] · Valentina Giannini[1,2] · Simone Mazzetti[1,2] · Michele Stasi[5] · Piergiorgio Cerello[7] · Daniele Regge[1,2]

Received: 21 March 2018 / Revised: 27 April 2018 / Accepted: 7 May 2018

Abstract

Objectives To compare unassisted and CAD-assisted detection and time efficiency of radiologists in reporting lung nodules on CT scans taken from patients with extra-thoracic malignancies using a Cloud-based system.

Human Neuroimaging: a “Big Data Challenge”



Predictive models based on multimodal and multidimensional data can be used either to characterize the pathology specific brain correlates (neuroimaging-based ***biomarker*** of a disease/condition) or to ***predict*** the single subject’s group membership.

Characterization of subjects with Autism Spectrum Disorders

Ricerca in collaborazione con IRCCS FONDAZIONE STELLA MARIS

https://arianna.pi.infn.it [2016-2018]

ARIANNA project

Ambiente di **R**icerca **I**nterdisciplinare per l'**A**nalisi di **N**euroimmagini **N**ell'**A**utismo

Regione Toscana | FAS Fondo Aree Sottoutilizzate 2007-2013 | REPUBBLICA ITALIANA

IRCCS Stella Maris Foundation, Viale del Tirreno 331, Pisa, Italy
FONDAZIONE STELLA MARIS — ISTITUTO DI RICOVERO E CURA A CARATTERE SCIENTIFICO
Prof. Filippo Muratori (Neuropsichiatria)
Dr. Michela Tosetti (Lab. Risonanza Magnetica)
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Dr Elena Tamburini

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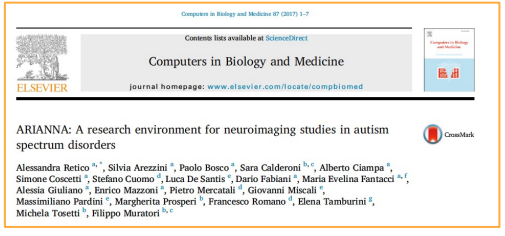
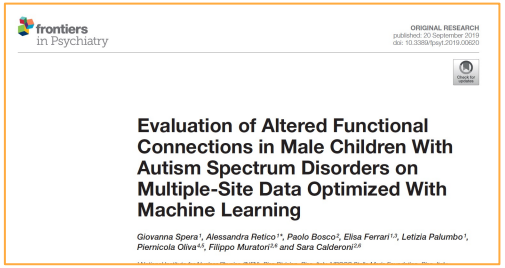
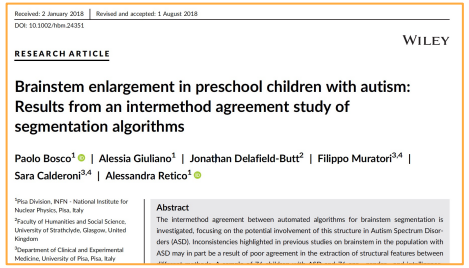
Istituto di Teoria e Tecniche dell'Informazione Giuridica del CNR
Dr. Pietro Mercatli
www.ittig.cnr.it

Net7 S.r.l, Via G. Carducci 60, 56017 Ghezzano - San Giuliano Terme, Pisa, Italy
www.netseven.it/ Dr. Luca De Santis

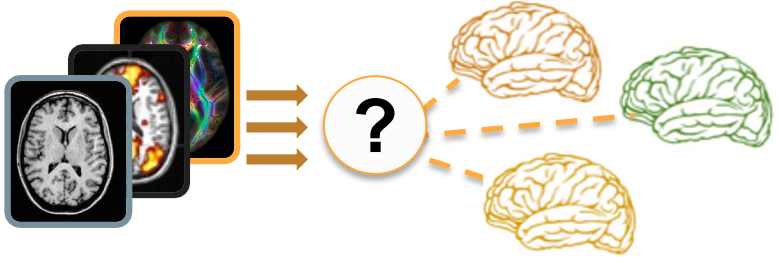

Computers in Biology and Medicine 87 (2017) 1–7
Contents lists available at ScienceDirect
Computers in Biology and Medicine
journal homepage: www.elsevier.com/locate/compbiomed
ARIANNA: A research environment for neuroimaging studies in autism spectrum disorders
Alessandra Retico, Silvia Arezzini, Paolo Bosco, Sara Calderoni, Alberto Ciampa, Simone Coscetti, Stefano Cuomo, Luca De Santis, Dario Fabiani, Maria Evelina Fantacci, Alessia Giuliano, Enrico Mazzoni, Pietro Mercatali, Giovanni Miscali, Massimiliano Pardini, Margherita Prosperi, Francesco Romano, Elena Tamburini, Michela Tosetti, Filippo Muratori


EJN European Journal of Neuroscience — FENS
European Journal of Neuroscience, pp. 1–11, 2017 doi:10.1111/ejn.13527
The effect of age, sex and clinical features on the volume of Corpus Callosum in pre-schoolers with Autism Spectrum Disorder: a case–control study
Alessia Giuliano, Irene Saviozzi, Paolo Brambilla, Filippo Muratori, Alessandra Retico and Sara Calderoni


frontiers in Psychiatry
ORIGINAL RESEARCH
Evaluation of Altered Functional Connections in Male Children With Autism Spectrum Disorders on Multiple-Site Data Optimized With Machine Learning
Giovanna Spera, Alessandra Retico, Paolo Bosco, Elisa Ferrari, Letizia Palumbo, Piernicola Oliva, Filippo Muratori and Sara Calderoni


WILEY
RESEARCH ARTICLE
Brainstem enlargement in preschool children with autism: Results from an intermethod agreement study of segmentation algorithms
Paolo Bosco | Alessia Giuliano | Jonathan Delafield-Butt | Filippo Muratori | Sara Calderoni | Alessandra Retico
Abstract

Open issue: is it possible to carry out a neuroimaging based *data-driven stratification of the heterogeneous population with ASD?*



Il progetto AIM (Artificial Intelligence in Medicine) - INFN CSN5

[2019 - today]

Resp. Naz.: A. Retico
Bari (S. Tangaro)
Bologna (D. Remondini)
Cagliari (P. Oliva)
Catania (M. Marrale)
Firenze (C. Talamonti)
Genova (A. Chincarini)
Lab. Naz. Sud (G. Russo)
Milano (C. Lenardi)
Napoli (G. Mettivier)
Pavia (A. Lascialfari)
Pisa (M.E. Fantacci)

L'Intelligenza Artificiale sarà alla base della prossima rivoluzione nella diagnostica e nella terapia medica

E' necessario sviluppare e validare estensivamente nuove strategie di elaborazione e analisi di dati e immagini, compresi gli approcci radiomici

Objectives	Methods	Applications	
AIM1: Multicenter data harmonization	image processing; data filtering; feature extraction; feature classification; data harmonization; image classification; pattern recognition; radiomics; complex network analysis; network models; machine learning; deep learning	Reliability of multicenter studies in neuroimaging and in mammography.	MRI, RX, PET
AIM2: Quantification		Quantification of radiotracer uptake in PET. Quantitative MRI methods.	MRI, PET, omics
AIM3: Predictive models		Radiomics and dosiomics in oncology. ML and DL for disease diagnosis	MRI, RX, RT dose, CT, omics

Analysis of lung CT in Covid-19

Il progetto AIM si fonda sulla collaborazione di lunga data con centri clinici italiani (ospedali / IRCCS) ed europei e con consorzi internazionali per la condivisione dei dati (EADC, ADNI, ABIDE, ENIGMA)

AIM1: Armonizzazione dei dati multicentrici

I dati raccolti da diversi siti e / o sistemi di acquisizione contengono "impronte digitali" locali, che possono nascondere le informazioni di interesse.

Questo problema è simile alla gestione degli **errori sistematici** degli esperimenti di Fisica

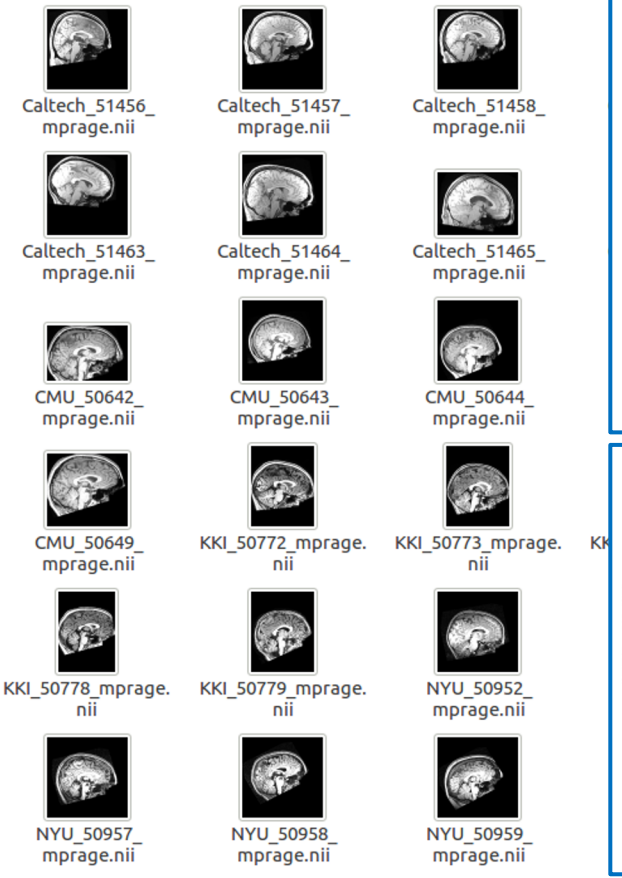
Autism Brain Imaging Data Exchange

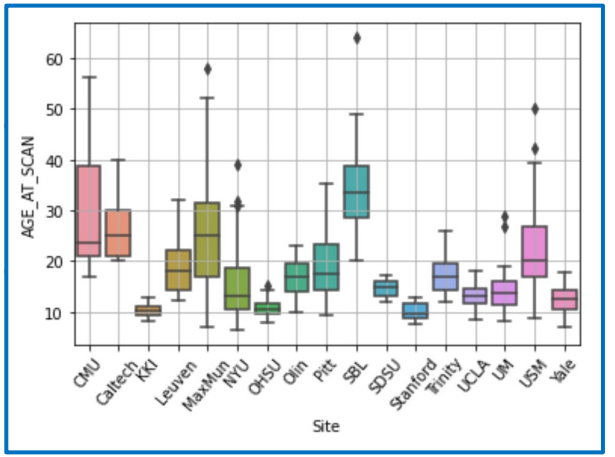
Dati MRI di piu' di 2000 soggetti

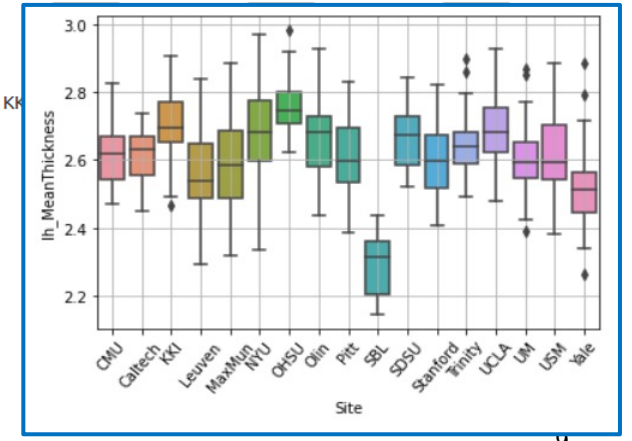
ABIDE

NITRC Neuroimaging Tools & Resources Collaboratory

http://fcon_1000.projects.nitrc.org/indi/abide



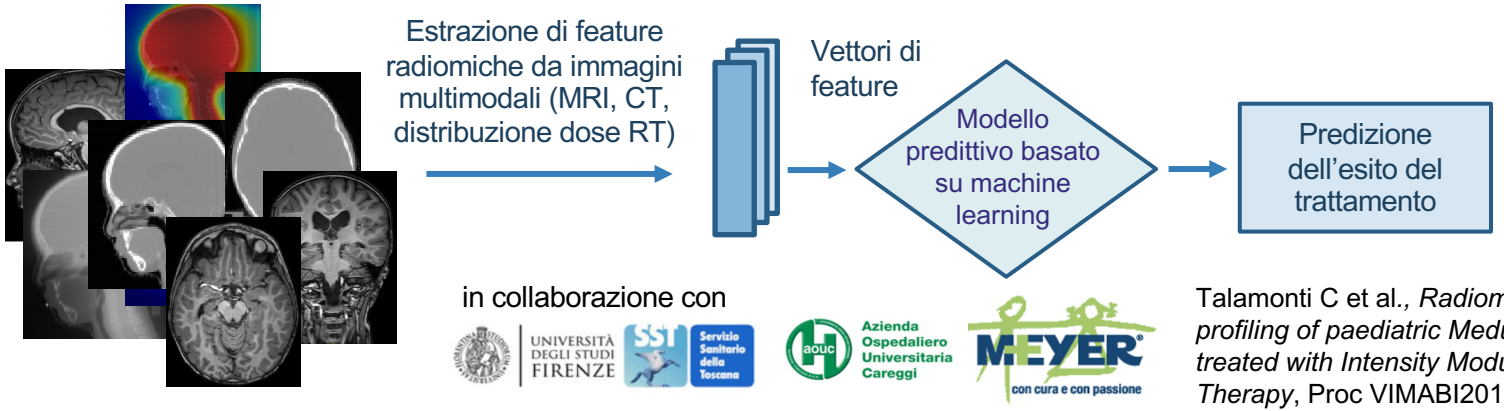




AIM3: Modelli Predittivi

- Le immagini e/o le loro caratteristiche radiomiche vengono analizzate con metodi di Machine Learning o Deep Learning per sviluppare modelli predittivi di diagnosi, prognosi o esito di trattamento.
- Alcuni esempi:

  AIM3.T1: Modelli predittivi di esito di trattamento radioterapico basati su Radiomica e Dosiomica (PI,FI)
  (Task leader: C. Talamonti, Univ. e INFN FI)



in collaborazione con

Talamonti C et al., *Radiomic and dosiomic profiling of paediatric Medulloblastoma tumours treated with Intensity Modulated Radiation Therapy*, Proc VIMABI2019

AIM3: Modelli Predittivi

AIM3.T2: Modelli predittivi in mammografia, CESM, DBT, BCT, and MRI (PI, CA, BA, NA)
(Task leader: M.E. Fantacci, Univ. e INFN PI)

Sinergia con il Progetto RADIOMX

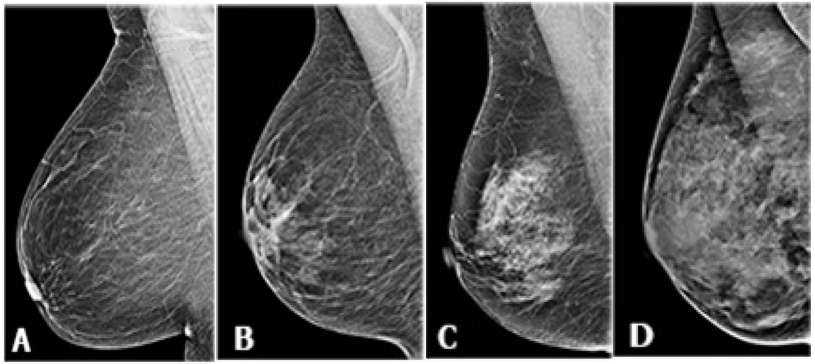
AZIENDA OSPEDALIERO UNIVERSITARIA PISANA

INFN Istituto Nazionale di Fisica Nucleare

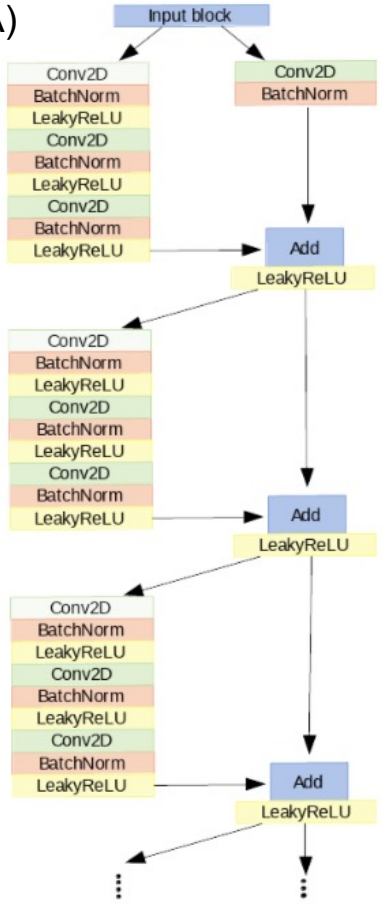
FONDAZIONE PISA

Goal: To contribute to develop a new personalized **dose index**, significant for each patient and each mammographic exam.

Automated identification of tissue density with residual CNN (R-CNN)

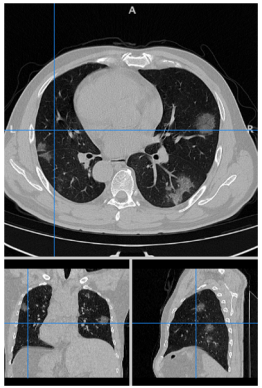


Dense/Non-dense	Left (%)	Right (%)	All (%)	BI-RADS	Left (%)	Right (%)	All (%)
Accuracy	84.4	88.8	89.4	Accuracy	73.3	76.7	77.3
Recall	82.3	89.9	90.0	Recall	72.1	79.2	77.1
Precision	85.5	87.7	88.9	Precision	76.6	75.2	78.6

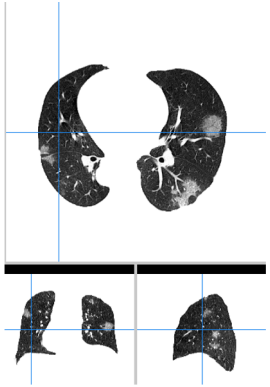


The AIM working group on lung CT analysis (AIM-Covid19-WG)

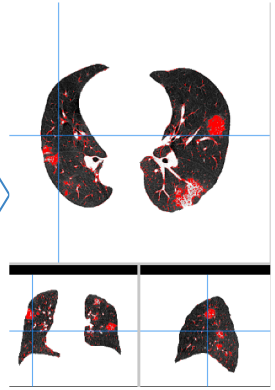
- AIM1: Multicenter Data Harmonization
- AIM2: Quantification
- AIM3: Predictive Models



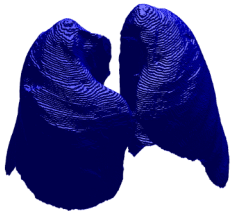
Lung volume segmentation



Quantification of lung parenchyma affected by ground glass (GG) opacities



Classical algorithms for lung segmentation fail when lung appearance is strongly affected by interstitial pneumonia

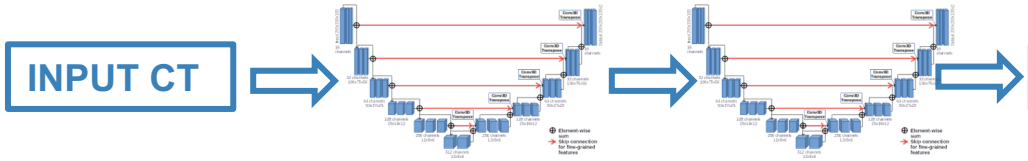


==> Deep learning segmentation methods need thousands of annotated cases to be “transferred” to accomplish this task

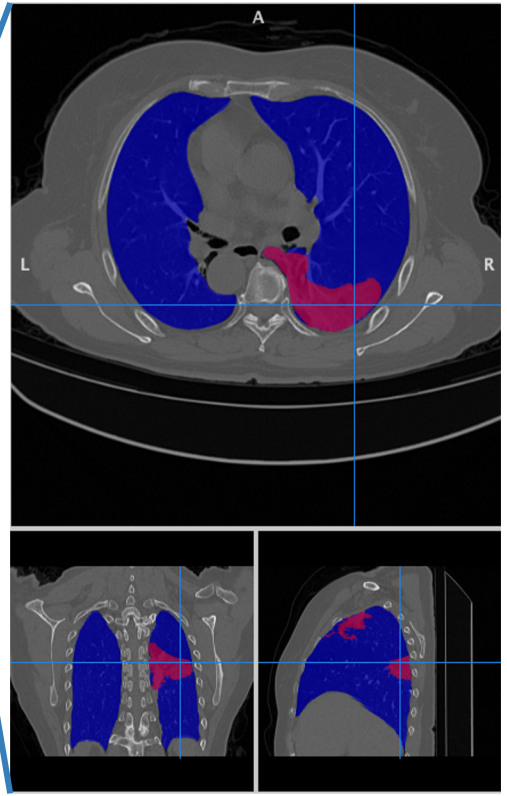
- Quantitative information on the amount of Covid-19 related lesions and their distribution, possibly combined with clinical and epidemiological patient’s information, may be relevant to set up predictive models for patients’ stratification, prognosis prediction, etc.
- Even only pure quantification modules, once properly validated, could be valuable tools for clinicians to set up large-scale population studies based on Radiomics

LungQuant: a Deep-Learning based quantification system

- A cascade of two trained U-nets for lung and lesion related to Covid-19 segmentation provides:
  - Lung mask
  - Lesion mask



  - The percentage of affected volume and the CT Severity Score (CT-SS)



- U-nets were trained on (limited!) publicly available datasets
- Computing resources available at INFN-Pisa, CINECA, EOS cluster of Department of Mathematics at Univ. of Pavia have been exploited
  - GPUs with at list 16 GB of RAM were necessary
  - Each run required ~12h to complete 100 epochs
  - ... Test to improve the performances still in progress!

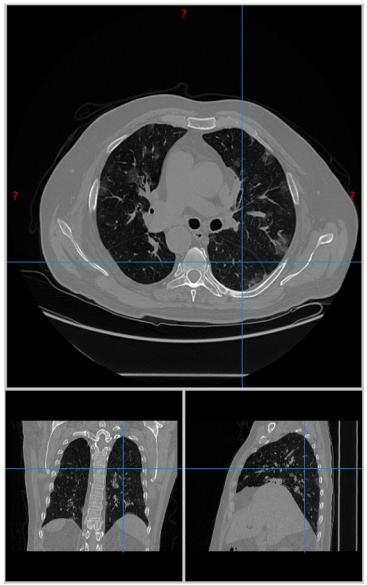
Unet$_1$ for lung segmentation

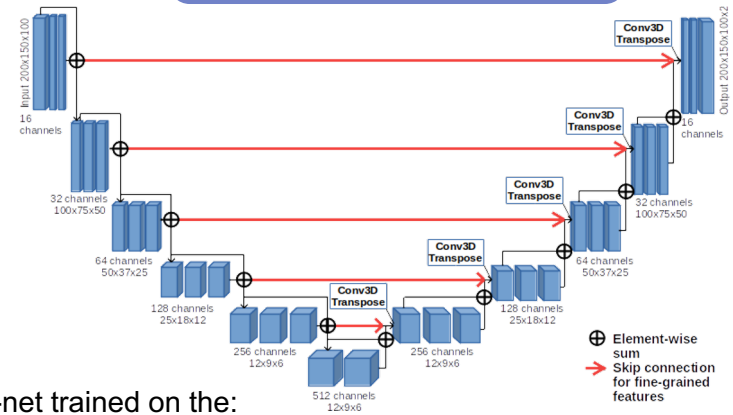
Windowing
[-1000, 1000] HU

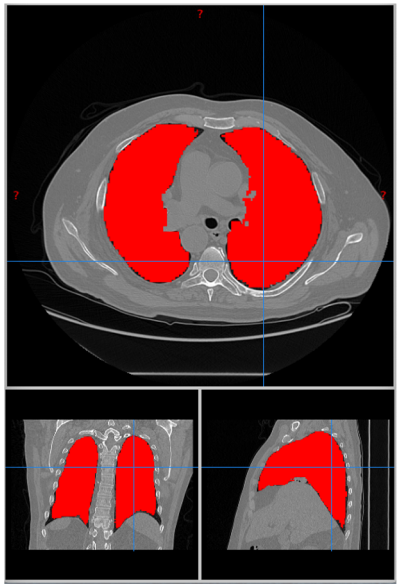
Resample to
200x150x100 array

U-net training and validation

Lung mask prediction







U-net trained on the:

- TCIA PleThora dataset (402 annotated CTs with lung masks)
- TCIA Lung CT Segmentation Challenge (60 CT, taken for dosimetry)
- MosMed CT0 subset (91 CT with normal lung, in-house lung segmentation SW to generate the reference lung masks)

Unet$_2$ for lesion segmentation

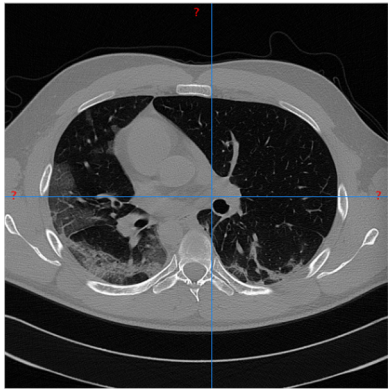
definition of the lung bounding box

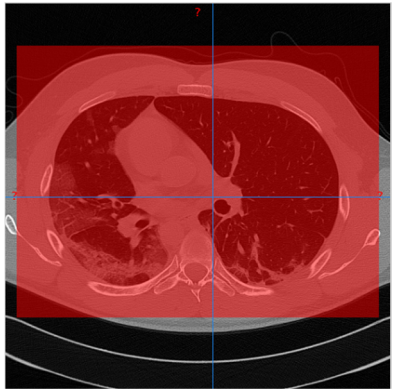
Windowing [-1000, 300] HU

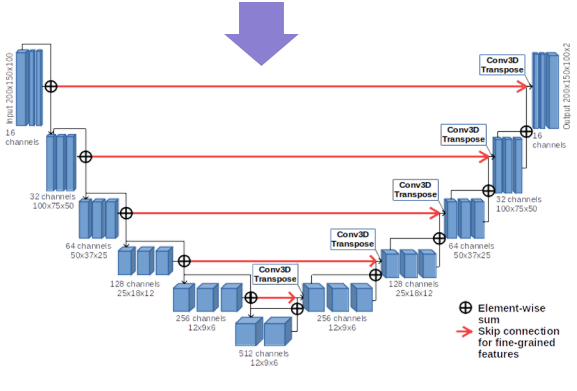
Resampling to 200x150x100 array

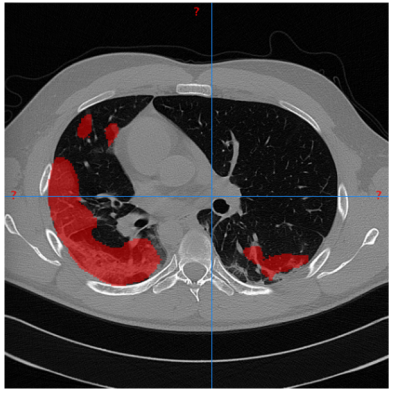
U-net training and validation

GG mask prediction



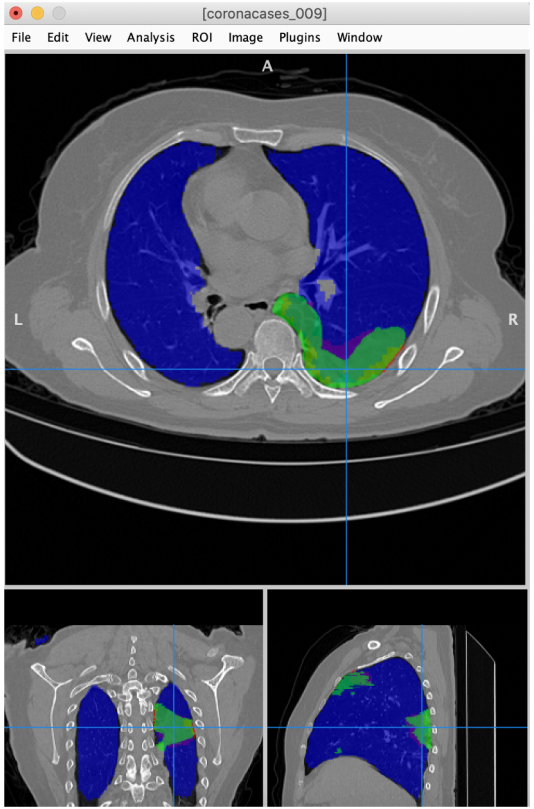






U-net trained on: the https://covid-segmentation.grand-challenge.org/ dataset (199 annotated CTs with COVID lesions, MICCAI endorsed event) and MosMed CT-1 (50 annotated CTs with COVID lesions)

The *LungQuant* system performance

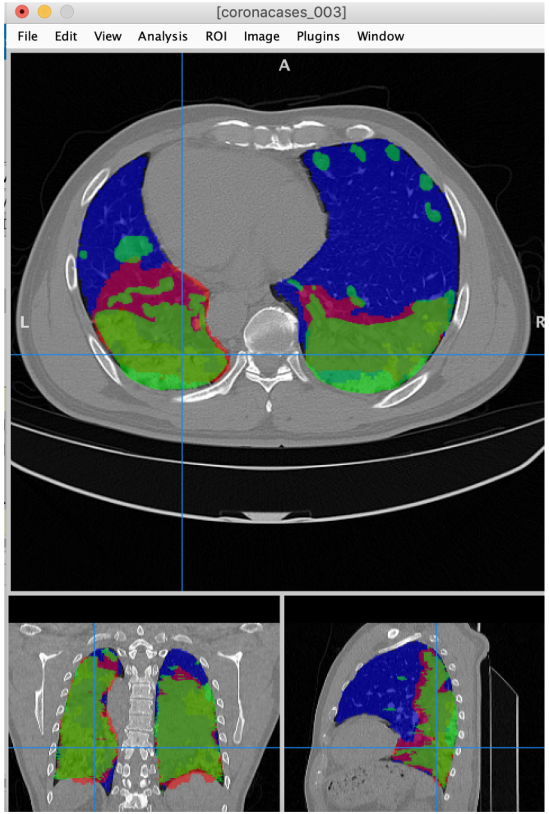


best

LungQuant system validation on the fully annotated (lungs and lesions) public benchmark dataset **COVID-19-CT-Seg**, https://doi.org/10.5281/zenodo.3757476 which is limited to <u>10 cases</u>

Lung segmentation (Dice coefficient)	Infection segmentation (Dice coefficient)
0.95 ± 0.01	0.66 ± 0.13

Blue: U-net lung mask
Red: U-net lesion mask
Green: reference lesion segmentation



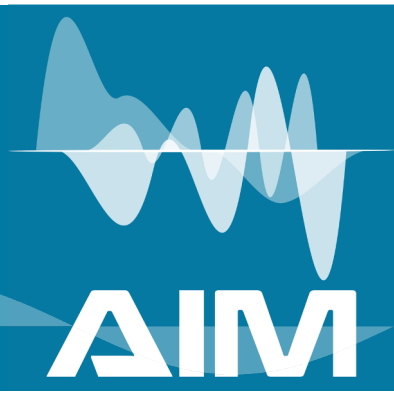
worst

Conclusioni

- L’imaging medico genera quotidianamente un'incredibile quantità di informazioni digitali (Big Data) che non vengono ancora sfruttate appieno:
  - E’ necessario sviluppare strategie automatizzate per il controllo della qualità dei dati e strategie di armonizzazione dei dati multicentrici
  - Sono necessari nuovi approcci computazionali per integrare le informazioni da dati multimodali (imaging, genetica, clinici, demografici, ecc.)
  - I dati della Ricerca devono essere FAIR (Findable, Accessible, Interoperable and Reusable) [proposal **FAIR-AIM** inviato per ***Bando GiovaniSi 2021*** in collaborazione con EBIT S.r.L.]

- Le analisi di dati medici basate su AI presentano diversi livelli di complessità, e necessitano di competenze multidisciplinari:
  - È auspicabile uno sforzo sinergico da parte di diversi professionisti, inclusi medici, fisici medici e informatici per raggiungere risultati rilevanti nel settore

Grazie per l’attenzione!



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