Exploring the potential and challenges of AI in clinical diagnostics and remote assistance of individuals

Andrea Berti, Rossana Buongiorno, Gianluca Carloni, Claudia Caudai, Giulio Del Corso, Danila Germanese, Eva Pachetti, Maria Antonietta Pascali and **Sara Colantonio**

National Research Council of Italy

Istituto di Scienza e Tecnologie dell'Informazione del Consiglio Nazionale delle Ricerche

Ital-IA ITALIA INTELLIGENZA ARTIFICIALE
cini National Lab AIIS

A multidisciplinary team @ISTI SILab

Andrea Berti
Medical Physicist

Rossana Buongiorno
Biomedical Eng

Gianluca Carloni
Biomedical Eng

Claudia Caudai
Mathematician

Sara Colantonio
Computer Scientist

Giulio Del Corso
Mathematician

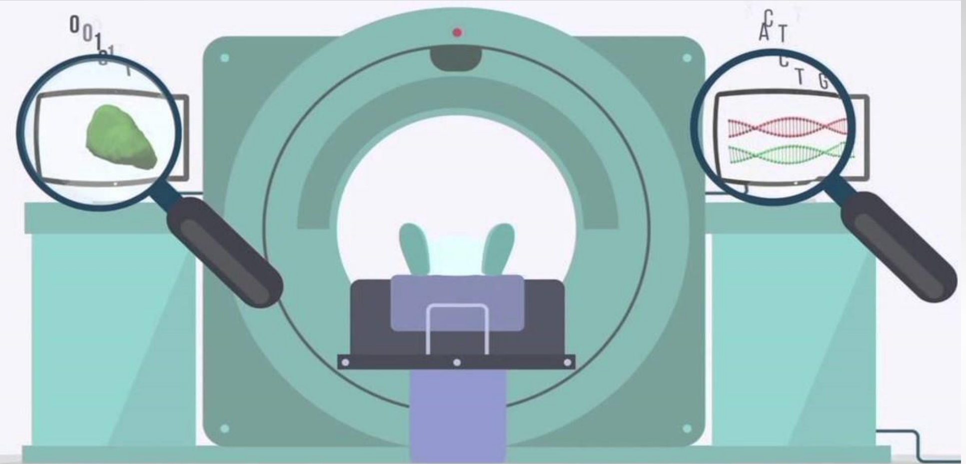
Danila Germanese
Biomedical Eng

Eva Pachetti
Biomedical Eng

Maria Antonietta Pascali
Mathematician

Two big areas

Visual Intelligence to support **image-based diagnosis and prognosis**



Credits: ALPHA GRID

Assistive technologies for **computational physiology** and **healthy living**

Providing **quantitative e repeatable** support to
- **detect anomalies**
- **quantify relevant information**
- **track disease progress**
- monitor **therapy interventions**

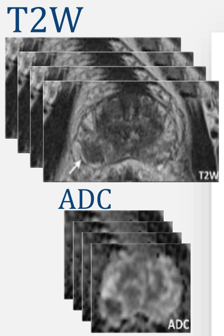
Personal devices to **self-monitor** or **remotely monitor vital parameters** for
- a long-lasting wellbeing
- **monitoring** health status and chronic disease conditions

Visual Intelligence for precision radiology

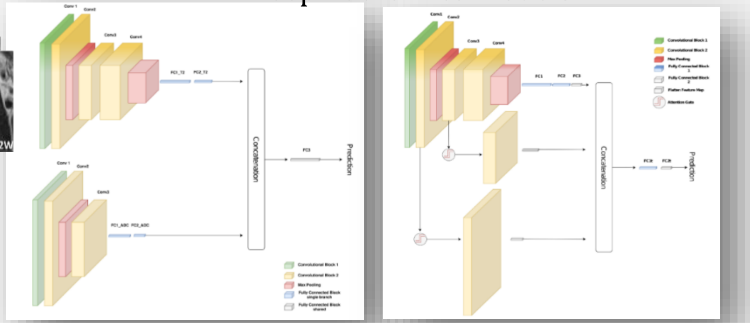
• Attention-based deep neural networks

Prostate Cancer Aggressiveness based on MRI

85 cases – 104 lesions on MRI scans



Deep Radiomics models

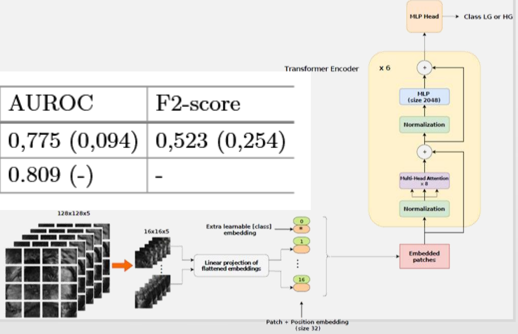


Framework	Test set	T2w	ADC	T2w+ADC
ML	2.0	0.750 [0.500, 1]	0.531 [0.250, 0.75]	0.625 [0.167, 1]
	multi PI-RADS	0.795 [0.615; 1]	0.500 [0.300; 0.715]	0.682 [0.455; 1]
AG-free DL on L-DS	2.0	0.667 [0.385, 0.849]	0.667 [0.355, 0.905]	0.727 [0.231, 1]
	multi PI-RADS	0.750 [0.568, 0.945]	0.714 [0.445, 0.883]	0.752 [0.564, 0.872]
AG-free DL on C-DS	2.0	0.775 [0.478, 1]	0.667 [0.392, 0.903]	0.700 [0.455; 0.858]
	multi PI-RADS	0.524 [0.200, 0.818]	0.547 [0.393, 0.780]	0.574 [0.286, 0.819]
AG DL on C-DS	2.0	0.875 [0.639, 1]	0.750 [0.455, 0.911]	0.667 [0.301, 1]
	multi PI-RADS	0.500 [0.278, 0.717	0.463 [0.234, 0.817]	0.288 [0.09, 0.529]

The AUROC values are reported as median [5th percentile, 95th percentile]. AG: attention gate; C-DS, cropped dataset; DL, deep learning; L-DS, lesion dataset; ML, machine learning.

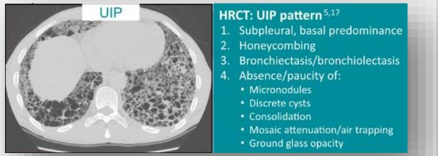
Prostate-X2

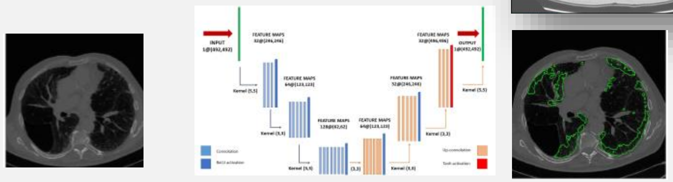
Model	Specificity	Sensitivity	Accuracy	AUROC	F2-score
Our ViT	0,750 (0,076)	0,567 (0,303)	0,700 (0,052)	0,775 (0,094)	0,523 (0,254)
CNN from [10]	-	0.794 (0.012)	0.738 (0.014)	0.809 (-)	-



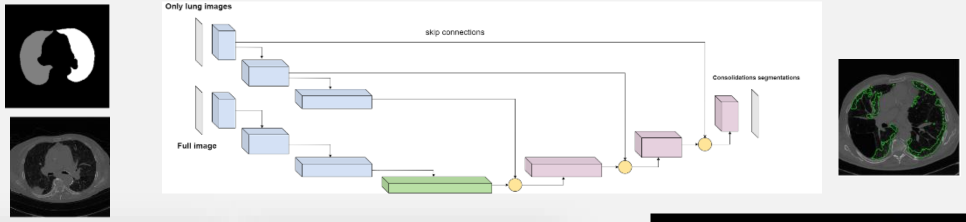
COVID-19 and Usual Interstitial Pneumoniae pattern segmentation and quantification

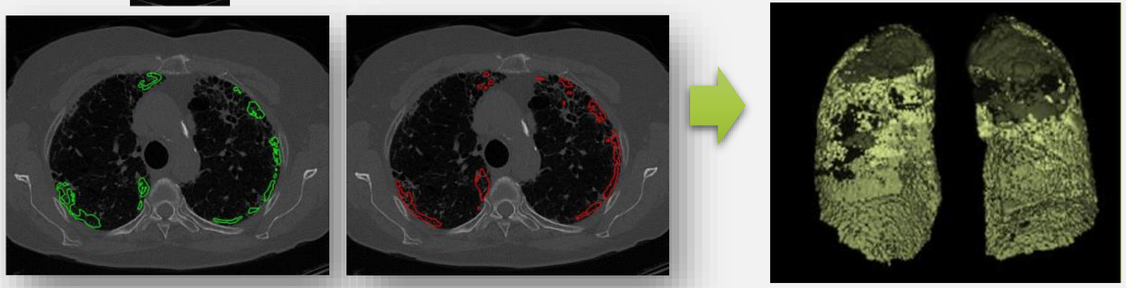
20 IPF patients – CT volumetric scans
Training/Test 13/7 cases
56 COVID-19 patients CT scans
Training/Test 36/20 cases





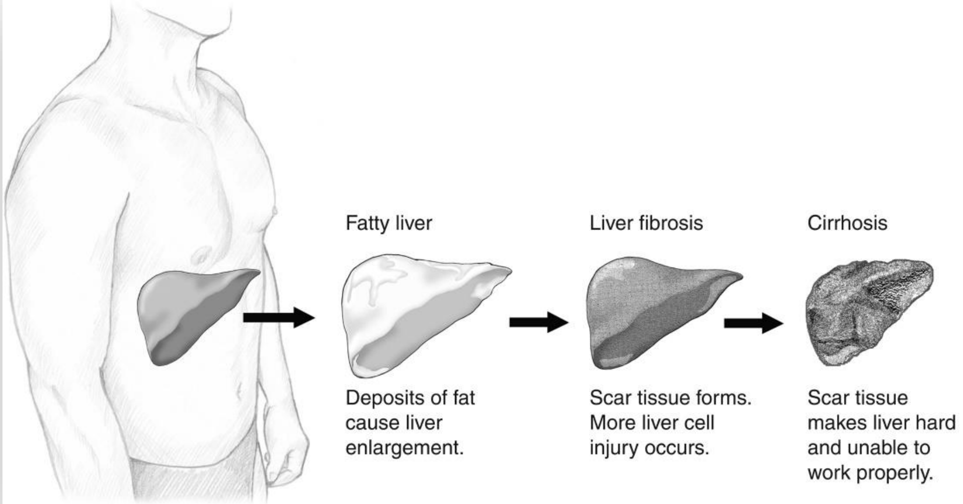
Dice score 86,5%± 12,7% Jaccard score 83,5%±15,1% 2,0%



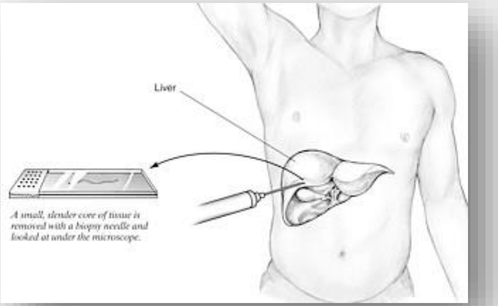


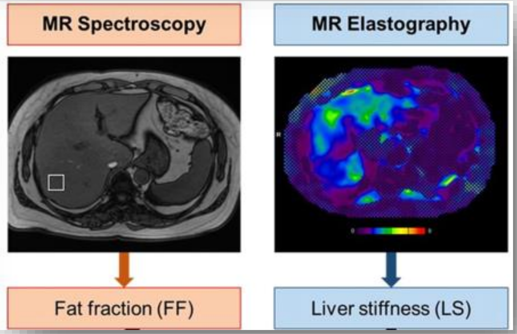
Visual Intelligence for precision radiology

NAFLD affects about 20-25% of people in Europe, 30-40% in US, about 25% worldwide



By NIDDK - https://commons.wikimedia.org/w/index.php?curid=82920619





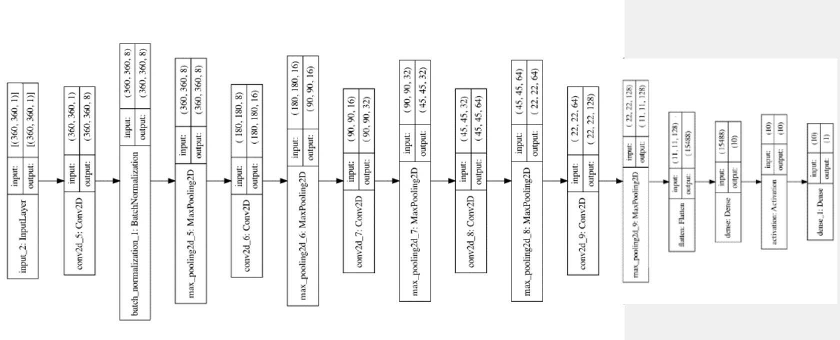
150 cases from 2 clinical sites

	n. of subjects	% of population
SEX (M:F)	73 : 77	48.7 : 51.3
	mean ± sd	min-max
AGE (years)	53.54 ± 12.66	20.0 - 75.3
BMI (kg/m^2)	24.86 ± 3.69	15.28 - 33.9
Fat (%)	4.50 ± 8.01	0.27 - 50.97

Stratified 4-fold cross-validation on 40 cases
Tested on 10 cases

Ultrasound clips

Regression CNN



Fat fraction (steatosis%)

RMSE 1.1127 Error Std Dev 0.7701

Uptake in clinical practice

- There is a gap between the scientific literature, news and the real clinical practice


BBC | Sign in | News | Sport | Reel | Worklife | Travel | Future | Mor

NEWS

Home | Video | World | UK | Business | Tech | Science | Stories | Entertainment & Arts | H

Health

Artificial intelligence diagnoses lung cancer

By James Gallagher
Health and science correspondent, BBC News

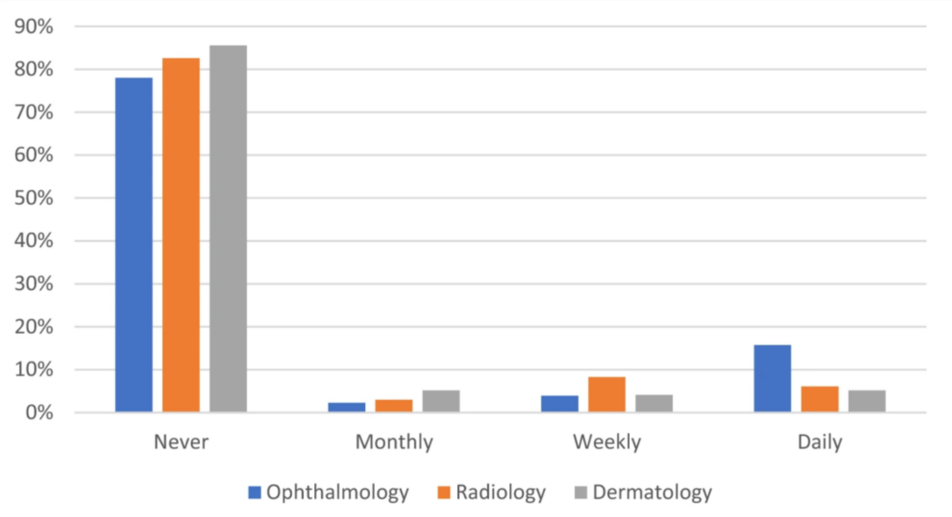
20 May 2019

Share

Article | Open Access | Published: 04 March 2021

A survey of clinicians on the use of artificial intelligence in ophthalmology, dermatology, radiology and radiation oncology

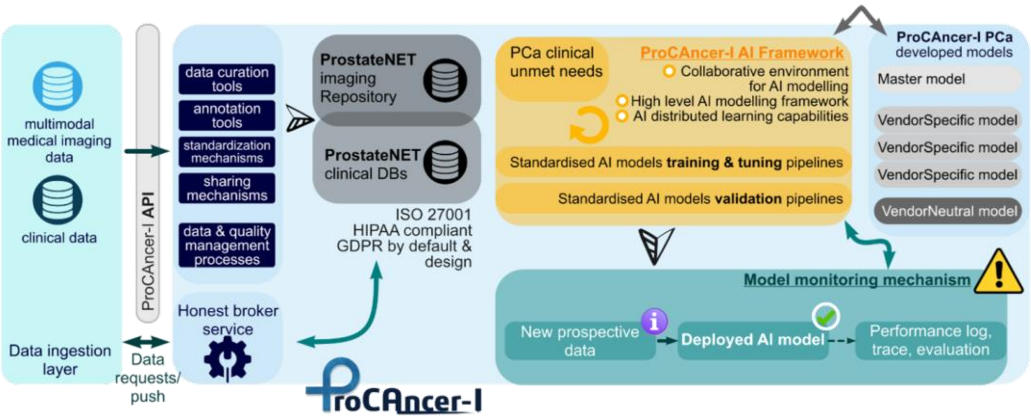
Jane Scheetz, Philip Rothschild, Myra McGuinness, Xavier Hadoux, H. Peter Soyer, Monika Janda, James J.J.



Large initiatives to overcome uptake challenges

ProCAncer-I

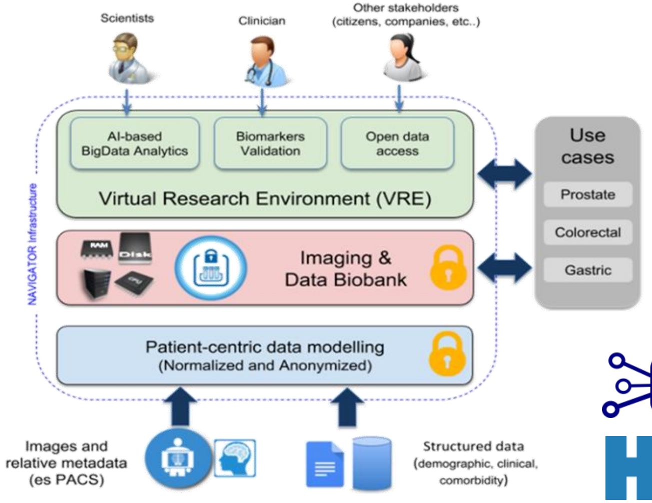
A sustainable **AI cloud-based platform** for the **development, verification** and **validation** of **trustworthy**, and **reliable AI models** for addressing **unmet needs** in the clinical management of **Prostate cancer**



https://www.procancer-i.eu/

NAVIGATOR

An **open imaging Biobank**, augmented with an **open-science oriented, Virtual Research Environment**, available for medical researchers and general clinical stakeholders, for ***radiomics* analyses** and **digital patient models** in oncology



http://navigator.med.unipi.it/

EUCAIM

EUCAIM is the cornerstone of the **European Cancer Imaging Initiative**, a flagship of the **Europe's Beating Cancer Plan** and a major contributor to the European **Health Data Space**. The project aims to foster innovative data-driven solutions thanks to a digital and **federated infrastructure of FAIR** cancer-related, de-identified, imaging data to address unmet **precision medicine**.

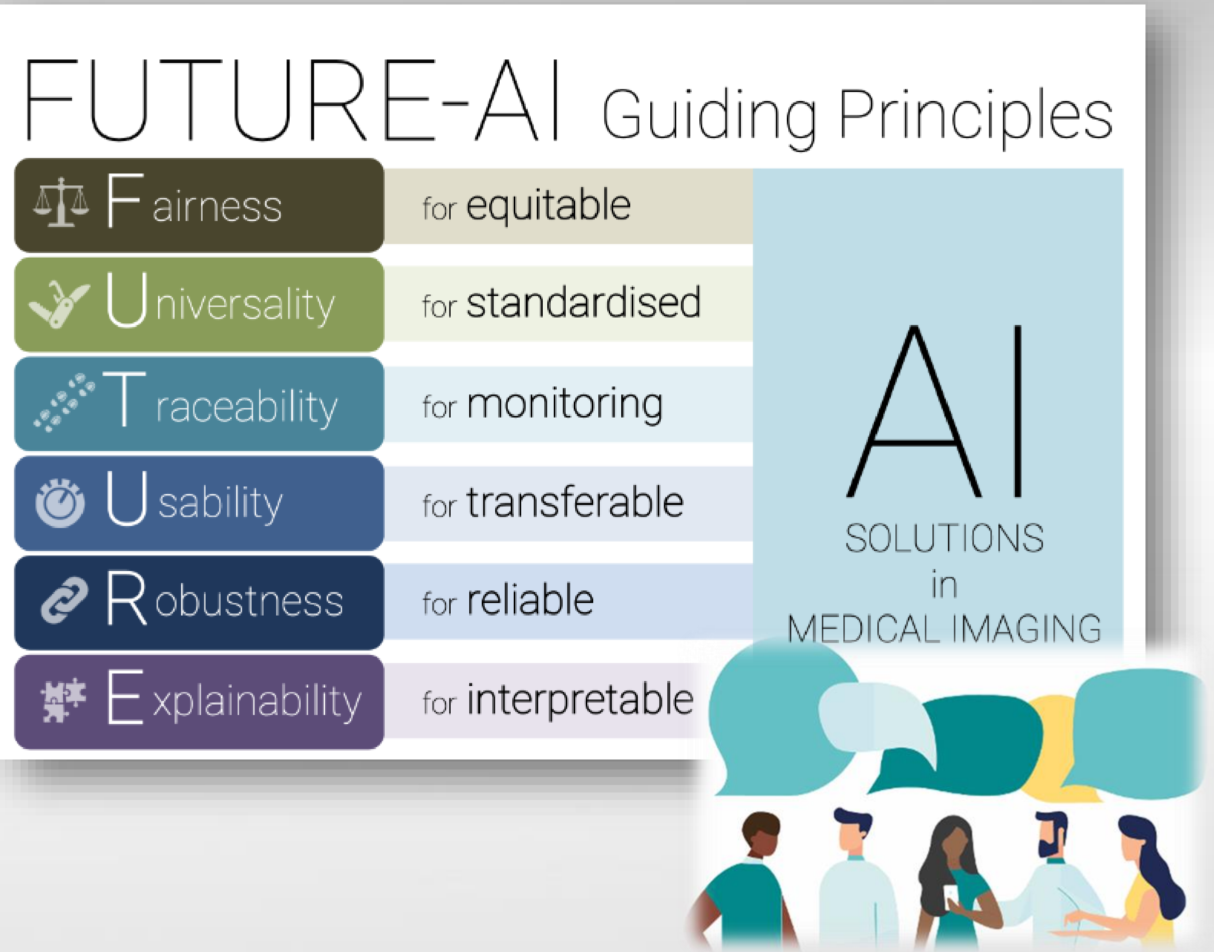
https://cancerimage.eu/

Addressing existing challenges for clinical uptake

ProCAncer-I chAImeleon PRIMAGE EUCAN IMAGE INCISIVE

FUTURE AI Best practices for trustworthy AI in medicine

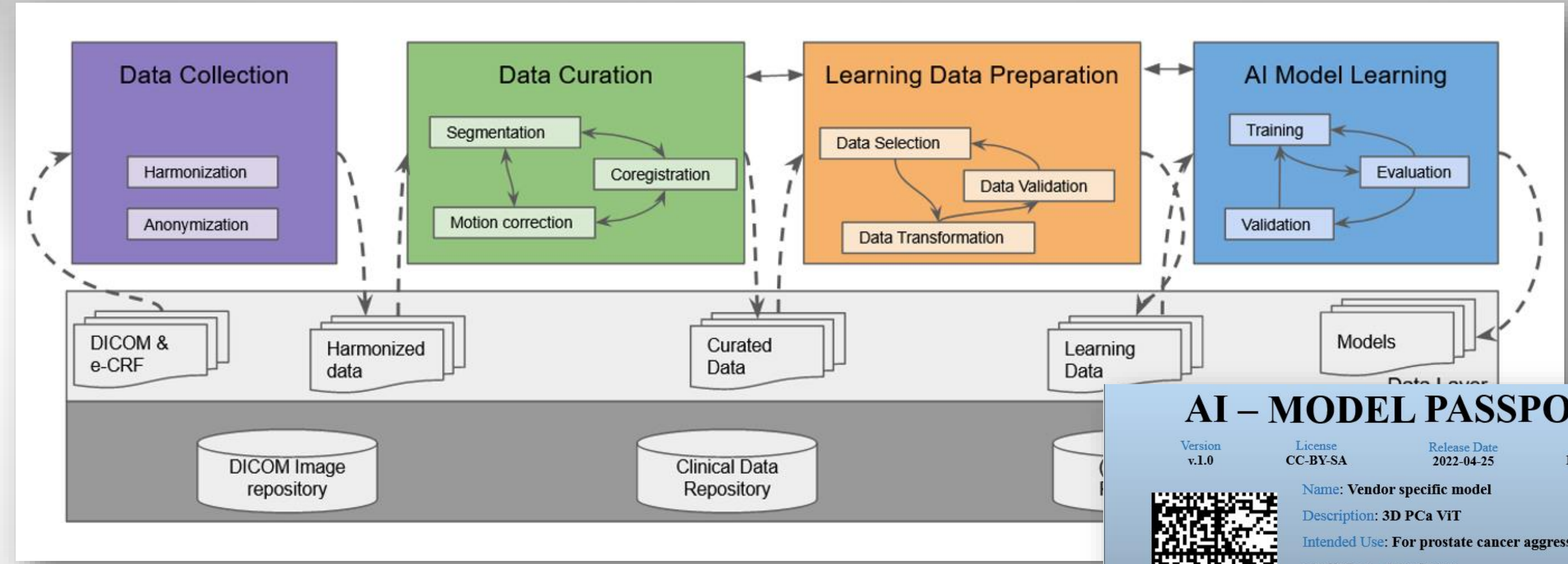
FUTURE-AI is an international, multi-stakeholder initiative for defining and maintaining concrete guidelines that will facilitate the design, development, validation and deployment of trustworthy AI solutions in medicine and healthcare based on six guiding principles: Fairness,

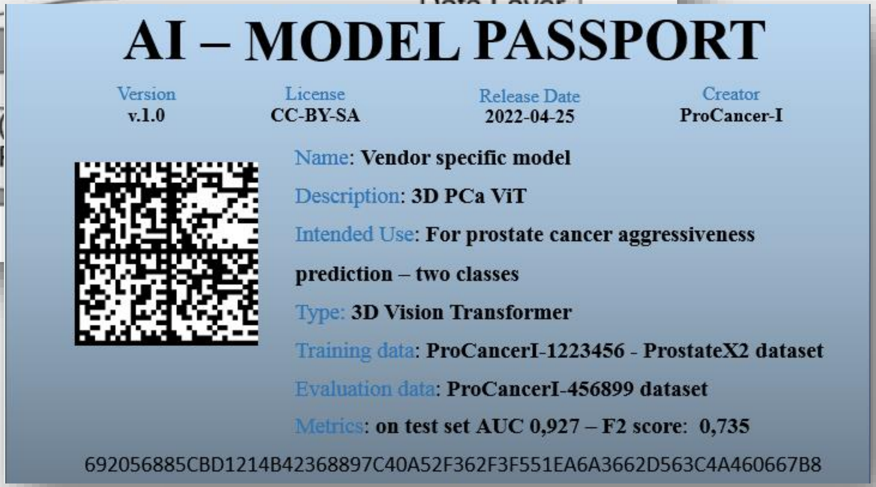


https://future-ai.eu/

Traceability: AI Model Passport

Definition of a metadata format for each phase of AI lifecycle

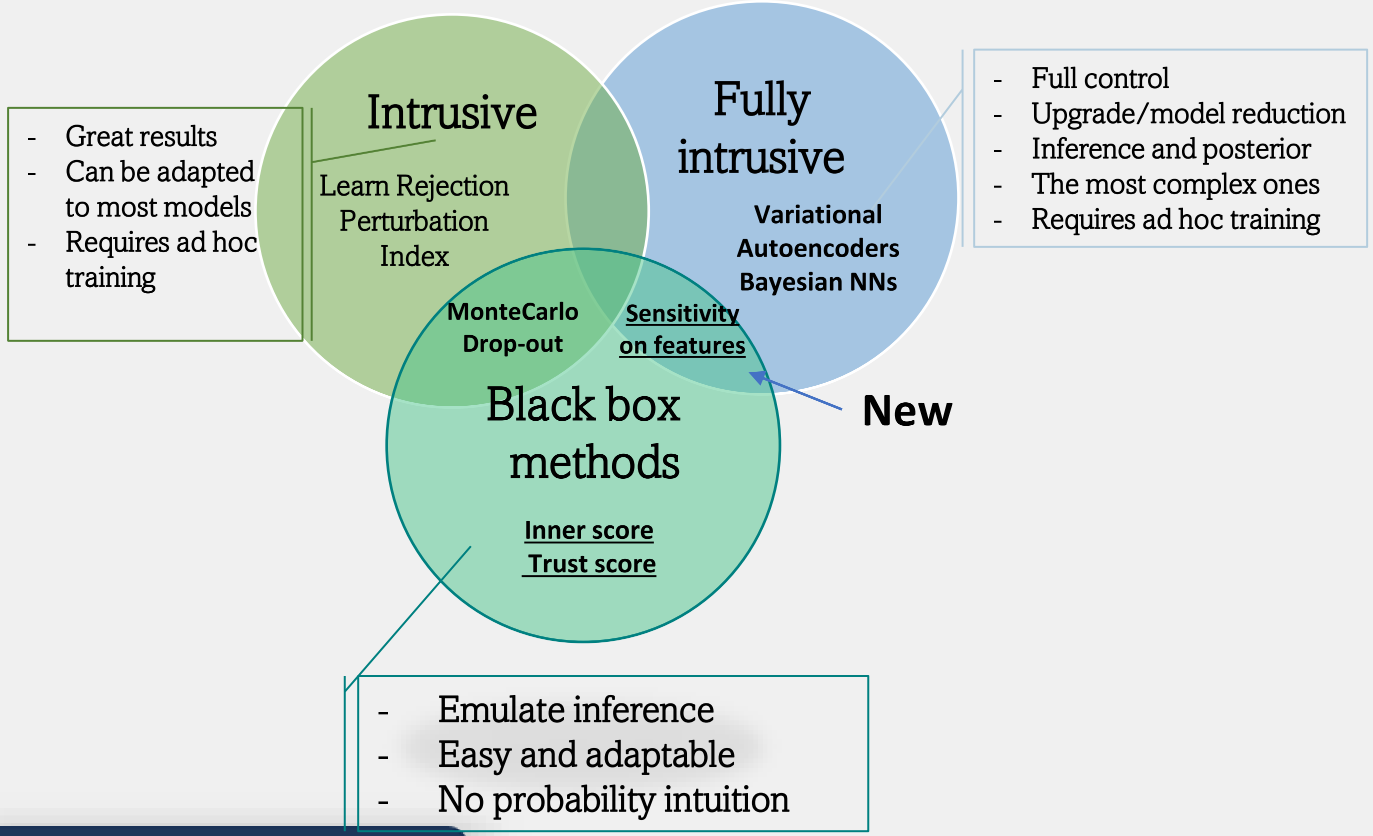




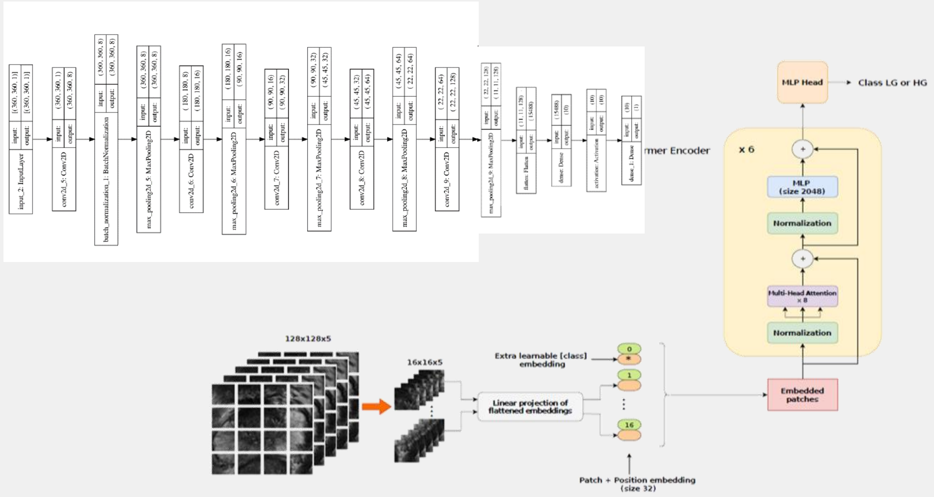
Traceability

Robustness: Uncertainty quantification

Uncertainty Quantification (UQ): the process of quantifying uncertainties associated with an AI model outputs



Experiments on a ViT and a regression network

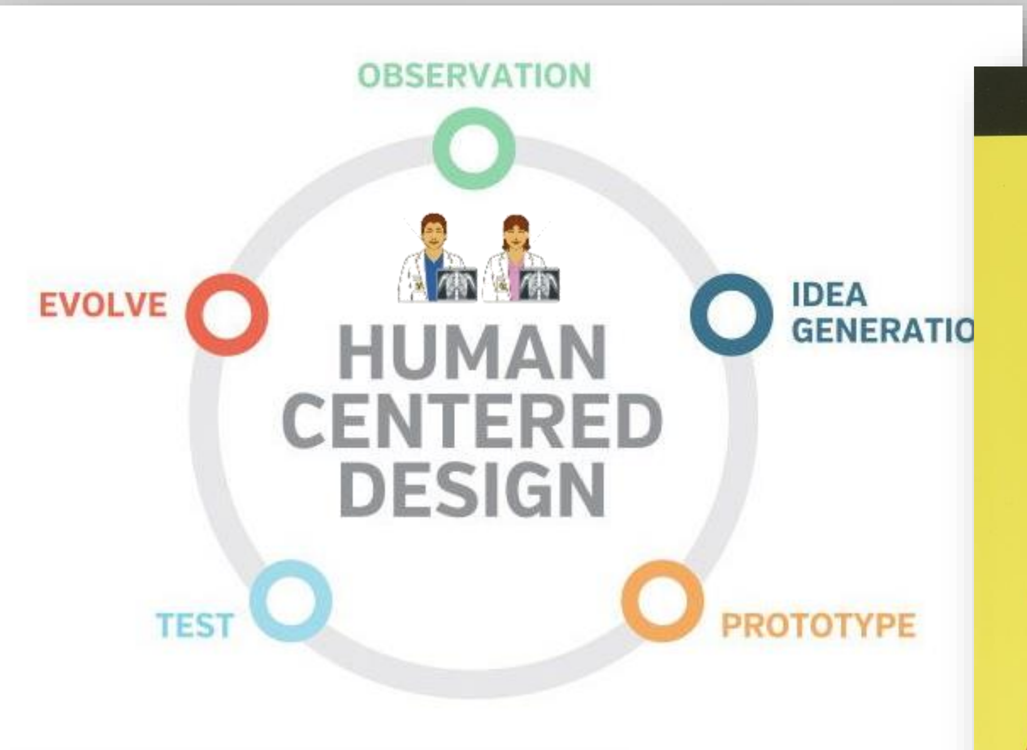


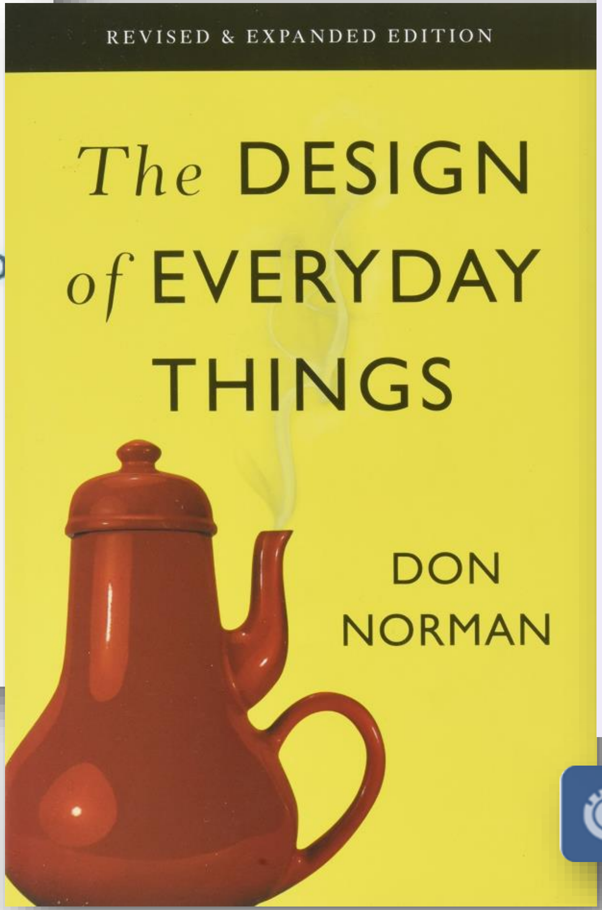
- **Inner score**
- **Trust score**
- **Topological uncertainty score**

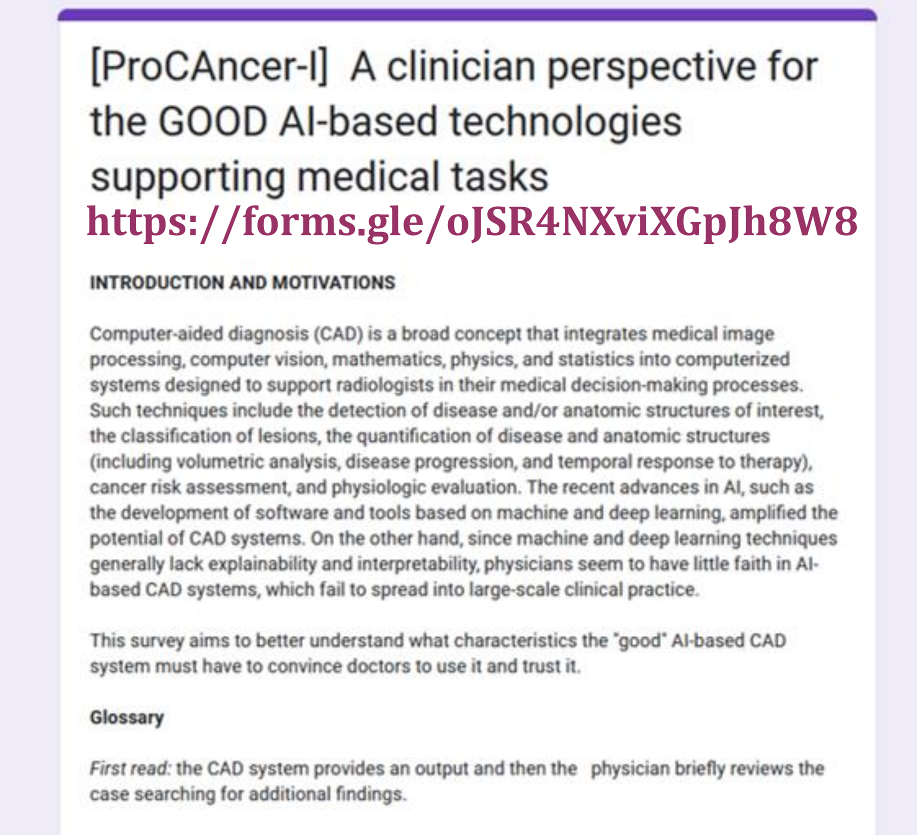
Robustness

Explainability: a co-design approach

Co-design field studies with end users – decision makers – radiologists, clinicians







[ProCAncer-I] A clinician perspective for the GOOD AI-based technologies supporting medical tasks
https://forms.gle/oJSR4NXviXGpJh8W8

INTRODUCTION AND MOTIVATIONS

Computer-aided diagnosis (CAD) is a broad concept that integrates medical image processing, computer vision, mathematics, physics, and statistics into computerized systems designed to support radiologists in their medical decision-making processes. Such techniques include the detection of disease and/or anatomic structures of interest, the classification of lesions, the quantification of disease and anatomic structures (including volumetric analysis, disease progression, and temporal response to therapy), cancer risk assessment, and physiologic evaluation. The recent advances in AI, such as the development of software and tools based on machine and deep learning, amplified the potential of CAD systems. On the other hand, since machine and deep learning techniques generally lack explainability and interpretability, physicians seem to have little faith in AI-based CAD systems, which fail to spread into large-scale clinical practice.

This survey aims to better understand what characteristics the "good" AI-based CAD system must have to convince doctors to use it and trust it.

Glossary

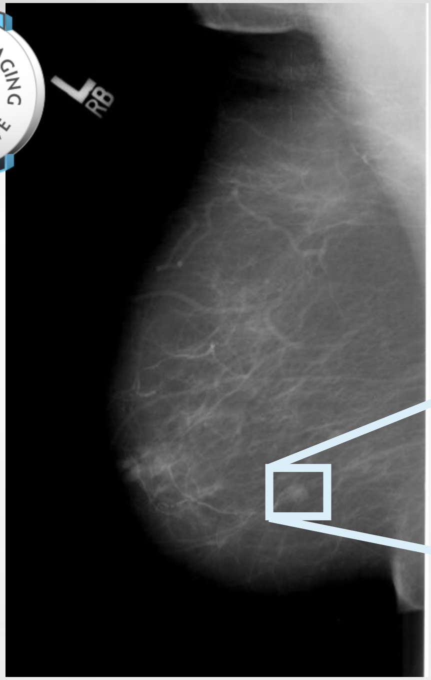
First read: the CAD system provides an output and then the physician briefly reviews the case searching for additional findings.

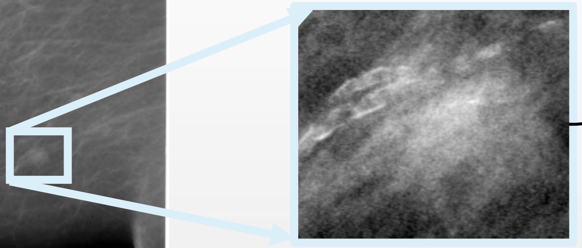
Explainability

Usability

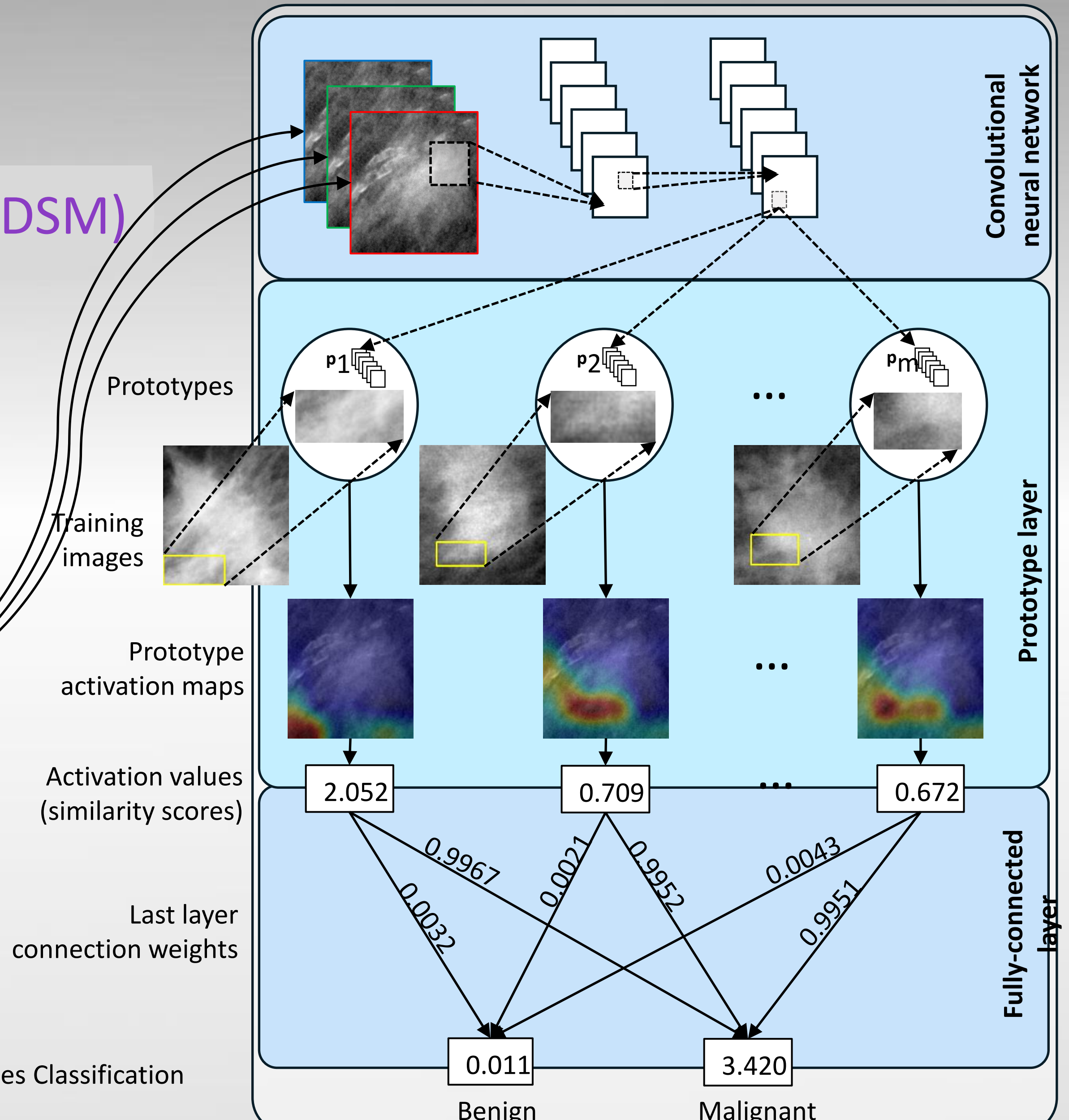
Prototypical part learning for breast cancer

CBIS-DDSM (Curated Breast Imaging Subset of DDSM)



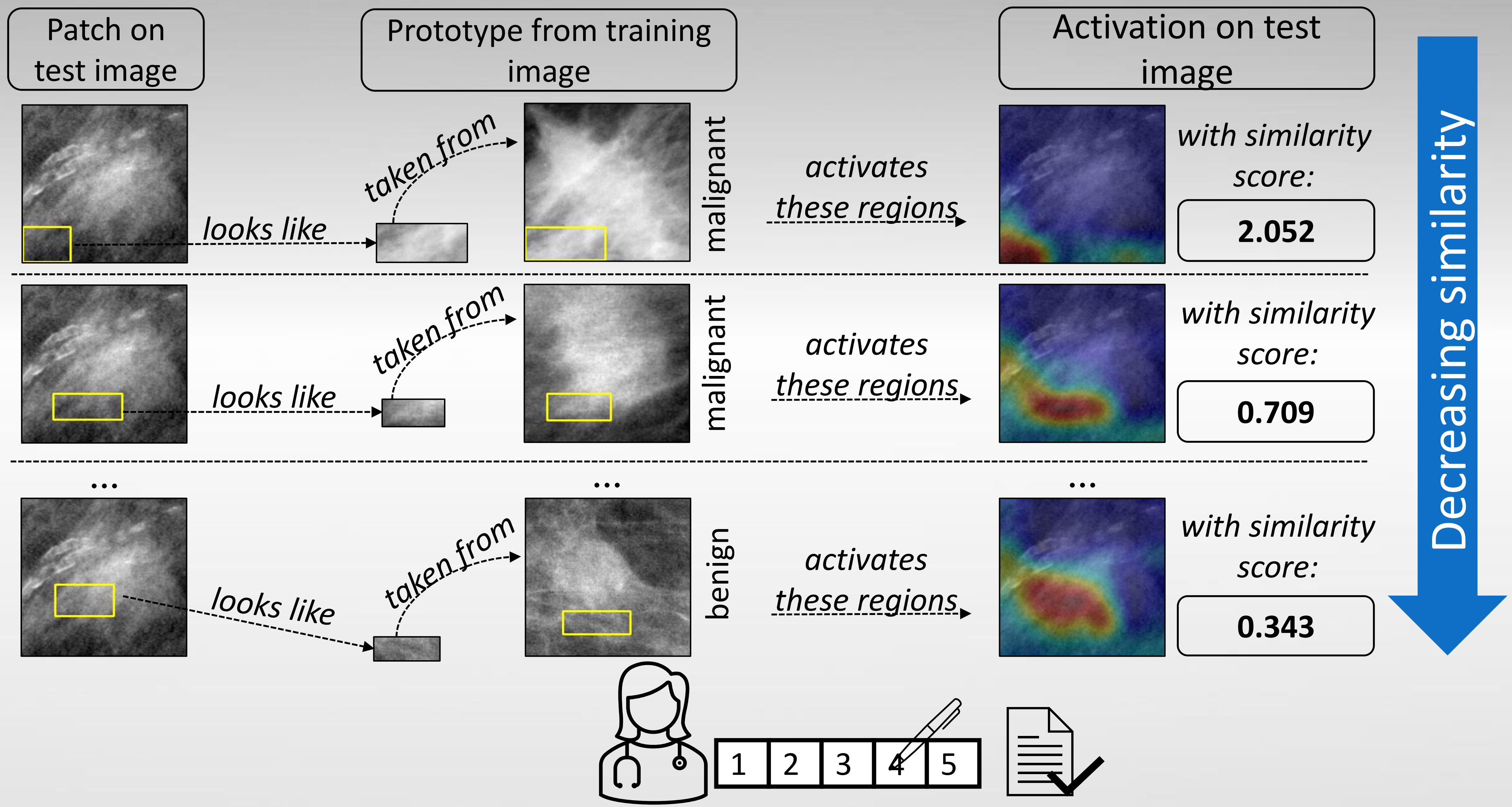


Training	Benign	577
	Malignant	637
Test	Benign	194
	Malignant	147



Carloni et al. On the Applicability of Prototypical Part Learning in Medical Images: Breast Masses Classification Using ProtoPNet. ICPR 2022 - https://tinyurl.com/3sue5mw2

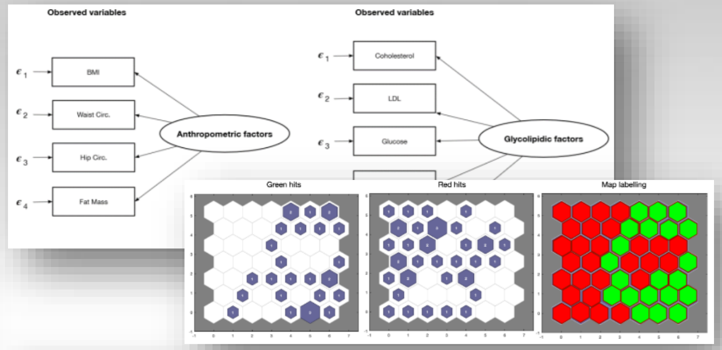
ProtoPNet's Explanations

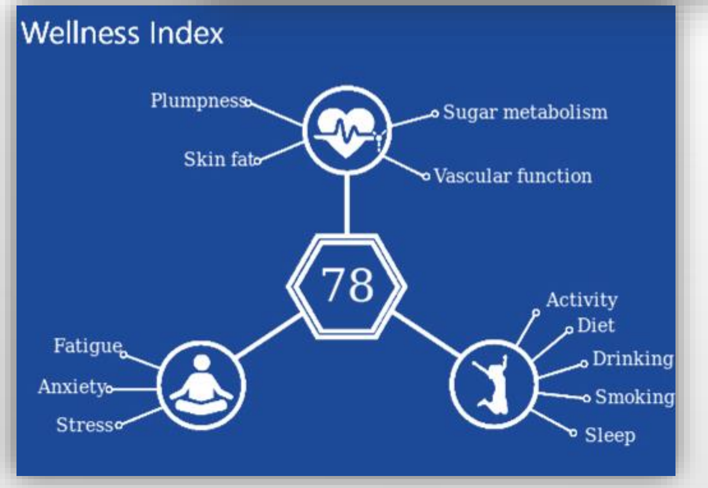


AI-powered assistive technologies

Visual Computing Lab

Prediction of cardio-metabolic risk based on health parameters measured through a smart mirror

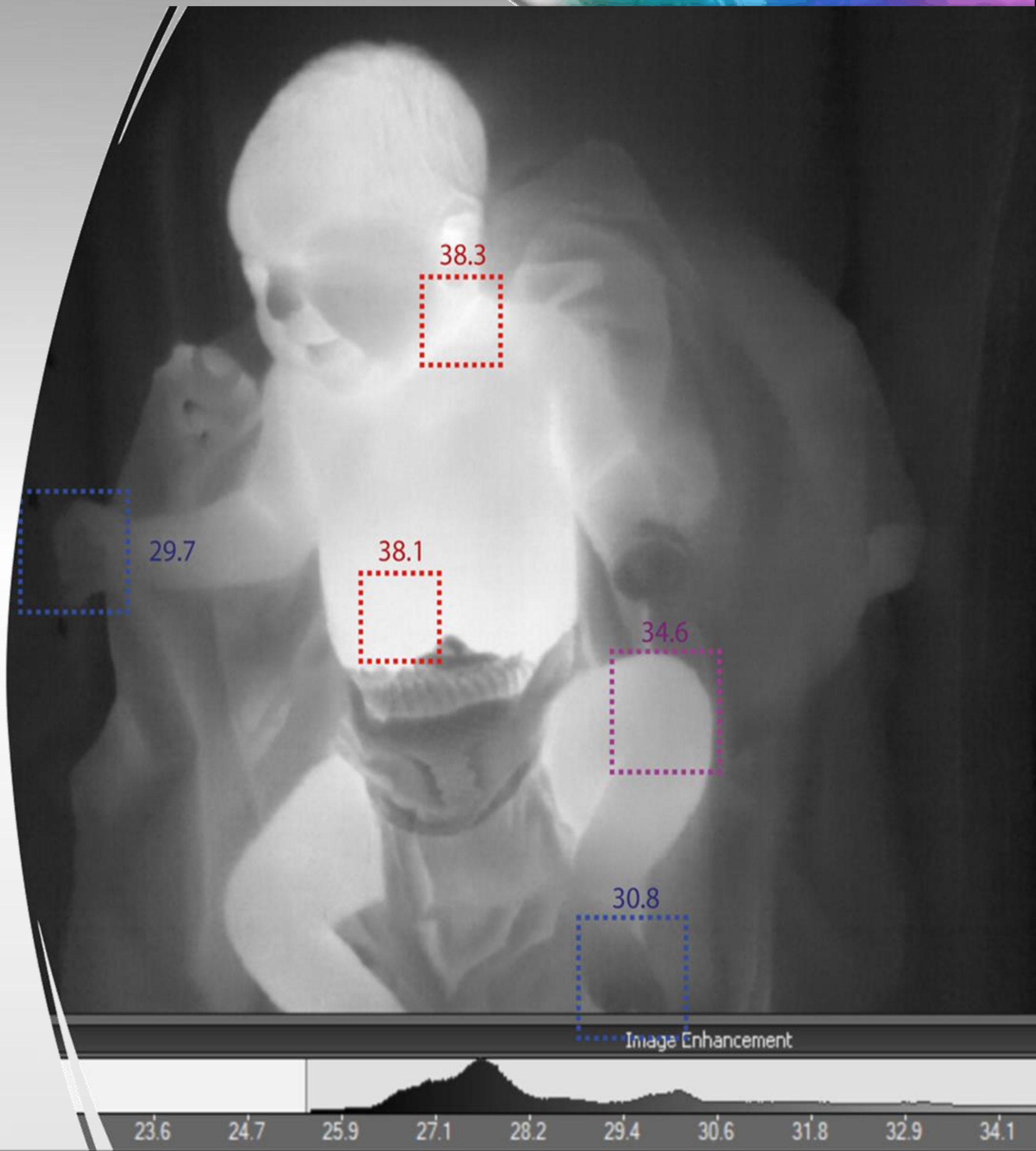




D Giorgi, L Bastiani, MA Morales, MA Pascali, S Colantonio, G Coppini, Cardio-metabolic risk modeling and assessment through sensor-based measurements, International Journal of Medical Informatics, 2022

AI-powered assistive technologies

New-born monitoring through thermal-cameras



Challenges to AI-powered AAL

Network on Privacy-Aware
Audio- and Video-Based Applications
for Active and Assisted Living

COST action 19121

https://goodbrother.eu/

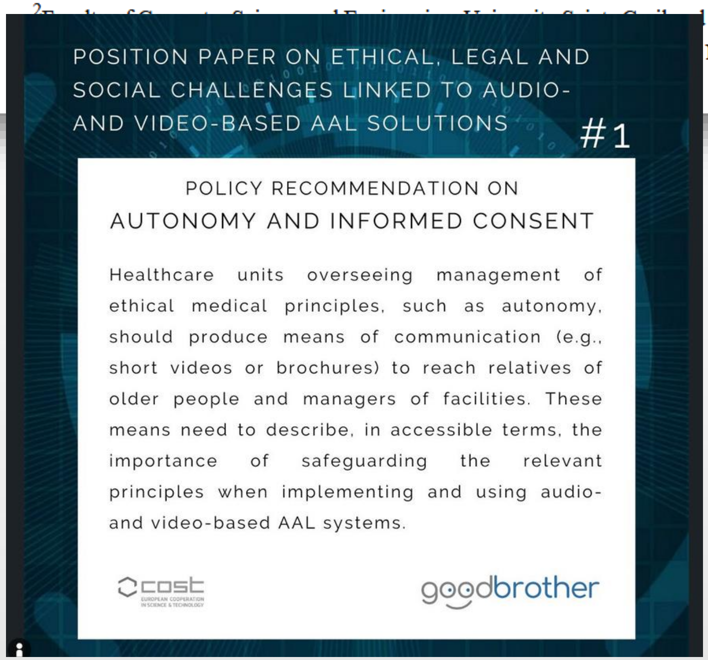

JOURNAL OF MEDICAL INTERNET RESEARCH

Review

Ambient Assisted Living: Scoping Review of Artificial Intelligence Models, Domains, Technology, and Concerns

Mladjan Jovanovic[1], PhD; Goran Mitrov[2], MSc; Eftim Zdravevski[2], PhD; Petre Lameski[2], PhD; Sara Colantonio[3], PhD; Martin Kampel[4], PhD; Hilda Tellioglu[4], PhD; Francisco Florez-Revuelta[5], PhD

[1]Department of Computer Science, Singidunum University, Belgrade, Serbia


POSITION PAPER ON ETHICAL, LEGAL AND SOCIAL CHALLENGES LINKED TO AUDIO- AND VIDEO-BASED AAL SOLUTIONS #1

POLICY RECOMMENDATION ON
AUTONOMY AND INFORMED CONSENT

Healthcare units overseeing management of ethical medical principles, such as autonomy, should produce means of communication (e.g., short videos or brochures) to reach relatives of older people and managers of facilities. These means need to describe, in accessible terms, the importance of safeguarding the relevant principles when implementing and using audio- and video-based AAL systems.


POSITION PAPER ON ETHICAL, LEGAL AND SOCIAL CHALLENGES LINKED TO AUDIO- AND VIDEO-BASED AAL SOLUTIONS #4

POLICY RECOMMENDATION ON
TECHNOLOGY-DRIVEN ISOLATION OR SOLITUDE

Governments should develop strategies to foster intergenerational solidarity by organising activities where citizens of different ages can interact, such as recreational activities or meetings where they can organise to help each other based on their respective strengths.

Bibliography

- D. Germanese, L. Mercatelli, S. Colantonio, V. Miele, M. A. Pascali, C. Caudai, N. Zoppetti, R. Carpi, A. Barucci, E. Bertelli, S. Agostini, Radiomics to predict prostate canceraggressiveness: A preliminarystudy, in: 2019 IEEE 19th International Conference on Bioinformatics and Bioengineering (BIBE), 2019,pp. 972–976.
- E. Bertelli, L. Mercatelli, C. Marzi, E. Pachetti, M. Baccini, A. Barucci, S. Colantonio, L. Gherardini, L. Lattavo, M. A. Pascali, S. Agostini, V. Miele, Machine and deep learning prediction of prostate cancer aggressiveness using multiparametric mri, Frontiers in Oncology 11 (2022). URL: https://www.frontiersin.org/articles/10.3389/
- E. Pachetti, S. Colantonio, M. A. Pascali, On the effectiveness of 3d vision transformers for the prediction of prostate cancer aggressiveness, in: P. L. Mazzeo, E. Frontoni, S. Sclaroff, C. Distante (Eds.),Image Analysis and Processing. ICIAP 2022 Workshops, Springer International Publishing, Cham,2022, pp. 317–328.
- M. Gabelloni, L. Faggioni, S. Attanasio, V. Vani, A. Goddi, S. Colantonio, D. Germanese, C. Caudai, L. Bruschini, M. Scarano, V. Seccia, E. Neri, Can magnetic resonance radiomics analysis discriminate parotid gland tumors? A pilot study, Diagnostics 10 (2020). URL:
- S. Colantonio, A. Salvati, C. Caudai, F. Bonino, L. D. Rosa, M. A. Pascali, D. Germanese, M. R. Brunetto, F. Faita, A deep learning approach for hepatic steatosis estimation from ultrasound imaging, in: K. Wojtkiewicz, J. Treur, E. Pimenidis, M. Maleszka (Eds.), Advances in Computational Collective Intelligence, Springer International Publishing, Cham,2021, pp. 703–714.
- R. Buongiorno, D. Germanese, C. Romei, L. Tavanti, A. De Liperi, S. Colantonio, Uip-net: A decoder-encoder cnn for the detection and quantification of usual interstitial pneumoniae pattern in lung ct scan images, in: Pattern Recognition. ICPR International Workshops and Challenges: Virtual Event, January 10–15, 2021,
- R. Borgheresi, A. Barucci, S. Colantonio, G. Aghakhanyan, M. Assante, et al., Navigator: an Italian regional imaging biobank to promote precision medicine for oncologic patients, European Radiology Experimental 6 (2022).
- A. Berti, G. Carloni, S. Colantonio, M. A. Pascali, P. Manghi, P. Pagano, R. Buongiorno, E. Pachetti, C. Caudai, D. Di Gangi, E. Carlini, Z. Falaschi, E. Ciarrocchi, E. Neri, E. Bertelli, V. Miele, R. Carpi,G. Bagnacci, N. Di Meglio, M. A. Mazzei, A. Barucci, Data models for an imaging bio-bank for colorectal, prostate and gastric cancer: the navigator project, in: 2022 IEEE-EMBS International Conference on Biomedical and Health Informatics (BHI), 2022
- S. Colantonio, The Design of Trustworthy AI System: a Deep Look into the Transparency of Data, Models, and Decisions, 2022

Bibliography

- K. Lekadir, R. Osuala, C. Gallin, N. Lazrak, K. Kushibar, G. Tsakou, S. Aussó, L. C. Alberich, K. Marias, M. Tsiknakis, S. Colantonio, N. Papanikolaou, Z. Salahuddin, H. C. Woodruff, P. Lambin, L. Martí-Bonmatí, Future-ai: Guiding principles and consensus recommendations for trustworthy artificial intelligence in medical imaging, 2021.
- R. Albertoni, S. Colantonio, P. Skrzypczyński, J. Stefanowski, Reproducibility of machine learning: Terminology, recommendations and open issues, 2023.
- G Carloni, A. Berti Andrea, MA Pascali, C. Iacconi. Chiara, S. Colantonio, On the Applicability of Prototypical Part Learning in Medical Images: Breast Masses Classification Using ProtoPNet, 2023. AIHA, ICPR 2022
- S. Aleksic, M. Atanasov, J. C. Agius, K. Camilleri, A. Cartolovni, P. Climent-Peerez, S. Colantonio, State of the art of audio- and video-based solutions for aal, 2022
- J. Fernández-Bermejo Ruiz, J. Dorado Chaparro, M. J. Santofimia Romero, F. J. Villanueva Molina, X. del Toro García, C. Bolaños Peño, H. Llumiguano Solano, S. Colantonio, F. Flórez-Revuelta,J. C. López, Bedtime monitoring for fall detection and prevention in older adults, International Journal of Environmental Research and Public Health 19 (2022).
- D Giorgi, L Bastiani, MA Morales, MA Pascali, S Colantonio, G Coppini, Cardio-metabolic risk modeling and assessment through sensor-based measurements, International Journal of Medical Informatics, 2022
- …

grazie

sara.colantonio@isti.cnr.it

National Research Council of Italy

Future AI guiding principles

- **Fairness** → To guarantee the same performance when applied to similarly situated individuals and across subgroups of individuals, including under-represented groups
- **Universality** → To enforce the definition and application of standards during algorithm development, evaluation and deployment
- **Traceability** → To adopt mechanisms for documenting and monitoring the whole development lifecycle as well as the functioning of the AI tools after deployment
- **Usability** → To guarantee AI apps are usable, acceptable and deployable for the end-users in medical imaging real-world practice
- **Robustness** → To ensure generalization capacity and reliability of AI models
- **Explainability** → To provide meaningful and actionable explanations to the clinicians about the predictions by an AI model