# Biomedical Image Computing & Machine Learning

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Department Image-Data-Signal

# Our BIOMED Group

## Biomed Team & Collaborators



- Within the Image-Data-Signal Department
- 3 faculty + ~15 PhD students + ~3 post-docs/RE focused on health data
- Several co-supervisions within Telecom faculties.
- External co-supervisions: hospitals, imaging manufacturers, startups, big pharma, others
- Strong **international** network of collaborators

### Current collaborators

Guerbet
GE Healthcare
PHILIPS Healthcare
INCEPTO
BIOSPACE LAB
SKAIROS
Simulate all, keep the best
Centre hospitalier Sainte-Anne
Institut Pasteur
PSL UNIVERSITÉ PARIS
ÉCOLE POLYTECHNIQUE
NeuroSpin

### International

POLITECNICO DI TORINO
HARVARD MEDICAL SCHOOL
UNIVERSITÀ DI TORINO
Imperial College London
COLUMBIA UNIVERSITY IN THE CITY OF NEW YORK
STEVENS
Yale University

# Machine Learning on biomedical Images

**Algorithms** + …. fundamental **models** on anatomical knowledge + image **physics** + "smart" **mathematical** formulation of a given task:

**1. Image enhancement, modeling & reconstruction**

➔ Any image type (CT, X-ray, MRI, US, PET/SPECT, OCT, BLI, small-animals, microscopy).

**2. Computer-aided diagnosis, predictive models, biomarkers**

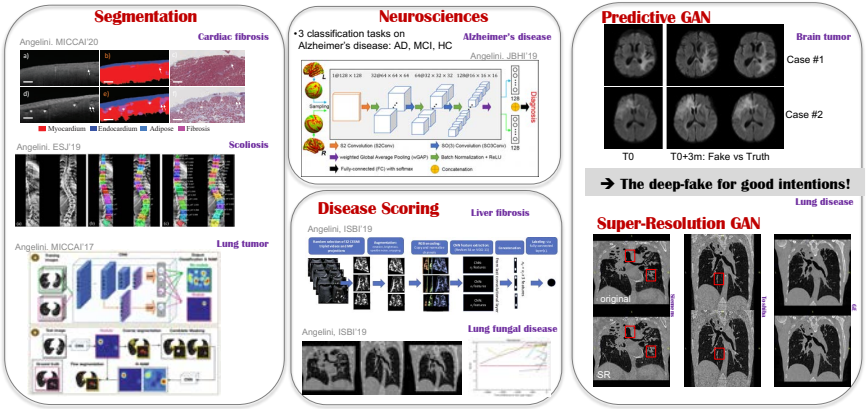
➔ Any pathology: cancer, scoliosis, neurodegenerative, COPD, fibrosis.
➔ Research & clinical quality scans, multiple scanners.

**3. Generic Methodological ML approaches**

**Multiple sollicitations**

**High transfer potential** (medical practice & techno)

## "Classic" AI on medical data




**4.a Very Large populations**

➔ **disease phenotyping**

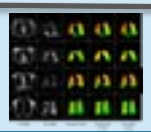
- EHR
- Multi omics
- Digital twins
- Synthetic control arms

Large population

Multi Omics

Federated Learning

**4.b Very Small population**



**eg. Novel Hyperpolarized MRI**
Quantification of lung ventilation defects on Hyperpolarized MRI.
*MRI Journal 2022*

**Growing our capacity**

**High clinical impact** (medical knowledge)

JAMA | Original Investigation

Association Between Long-term Exposure to Ambient Air Pollution and Change in Quantitatively Assessed Emphysema and Lung Function

IF = 56

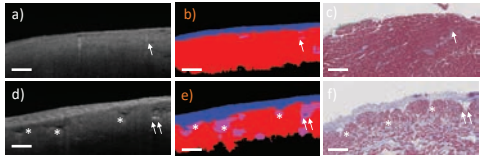

Meng Wang, PhD; Carrie Pistenmaa Aaron, MD; Jaime Madrigano, ScD; Eric A. Hoffman, PhD, Elsa Angelini, PhD; Jie Yang, PhD; Andrew Laine, PhD; Thomas M. Vetterli, MS; Patrick L. Kinney, ScD; Paul D. Sampson, PhD; Lianne E. Sheppard, PhD; Adam A. Szpiro, PhD; Sara D. Adar, ScD; Kipruto Kirwa, PhD; Benjamin Smith, MD, MS; David J. Lederer, MD, MS; Ana V. Diez-Roux, MD, PhD; Sverre Vedal, MD; Joel D. Kaufman, MD, MPH; R. Graham Barr, MD, DrPH

# Deep Learning in Medical Imaging

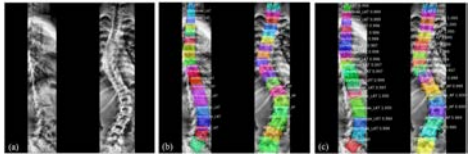
1,2 **Tasks**

## Segmentation

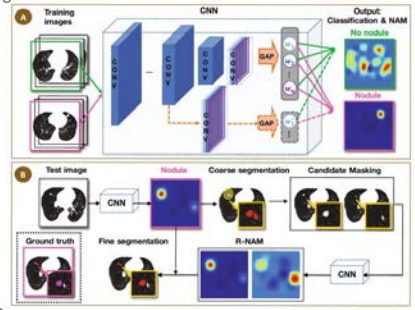
Angelini. MICCAI'20 — **Cardiac fibrosis** — **OCT**




Angelini. ESJ'19 — **Scoliosis** — **X-rays**



Angelini. MICCAI'17 — **Lung tumor** — **CT scans**

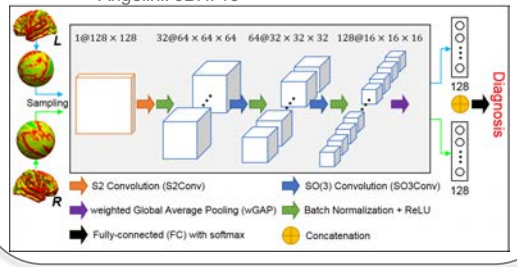



## Classification

- classification in 3 classes: AD, MCI, HC

**Alzheimer's disease** — **MRI**

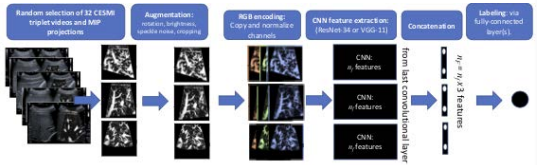
Angelini. JBHI'19



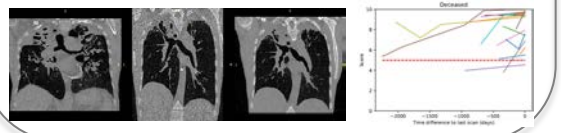

## Disease Scoring

**Liver fibrosis** — **Ultrasound videos**

Angelini, ISBI'19

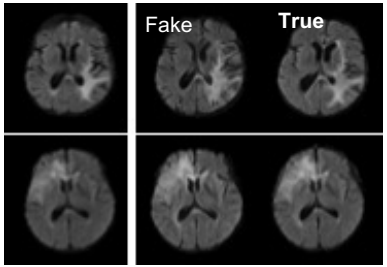


Angelini, ISBI'19 — **CT scans** — **Lung fungal disease**



## Generative models

**Brain tumor** — **MRI**

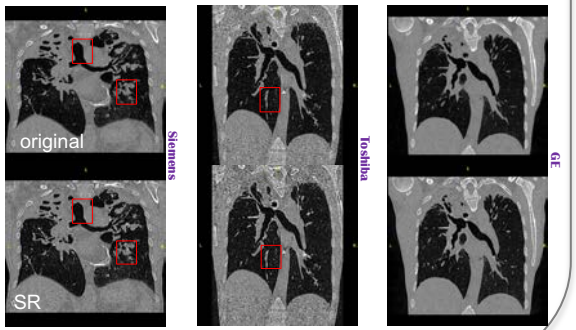



T0 — T0+3months = progression

➔ **The deep-fake for good intentions!**

## Super-Resolution GAN

**Lung disease** — **CT scans**




Angelini, ISBI'19

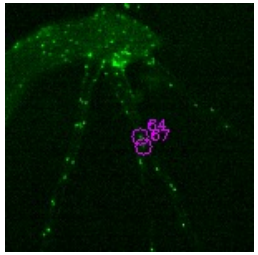
# Deep Learning in Biological Imaging

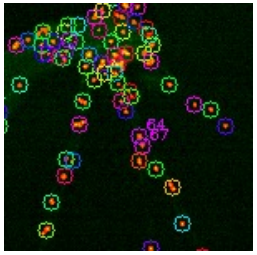
1,2 **Tasks**

## Particle tracking

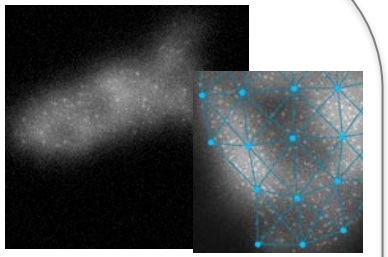
**Live animal: Hydra Vulgaris**

Fluorescence on neurons



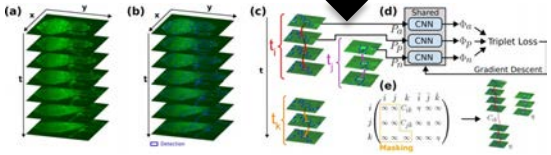


[Lack of manual gt]



**Simulator** with realistic deformations

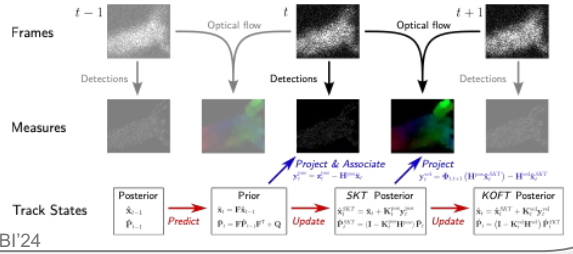
Contrastive **SSL**




Angelini. ISBI'23

DL

**Kalman**
Optical Flow
**Tracking**

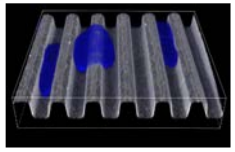



Angelini. ISBI'24

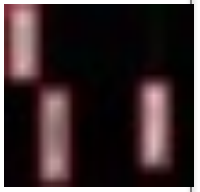
## Phenotyping

**Micro-groove cell imaging**

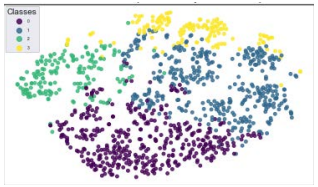
Fluorescence on nuclei

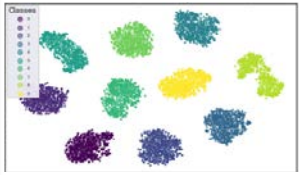


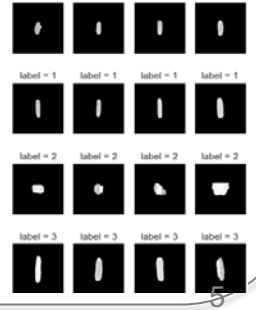
DL **Cellpose** Segmentation



**cVAE** for WT vs mutants cells phenotyping







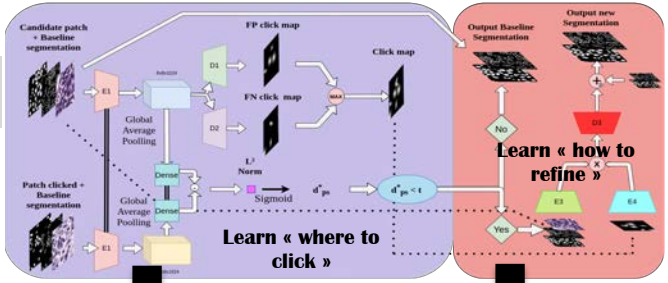
IP PARIS

## "Smart" segmentation corrections on large WSIs

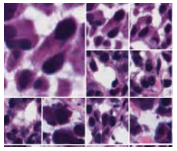
Nuclei segmentation H&E WSI

Angelini. ICIP'23


① From 1 click

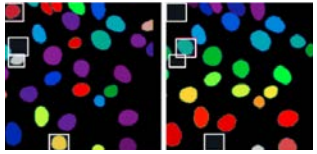



Similar patches



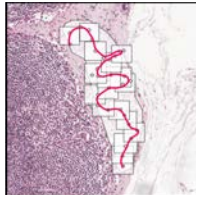
DL

Similar corrections

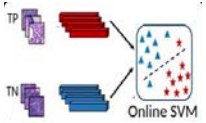


original corrected

② From 1 scribble



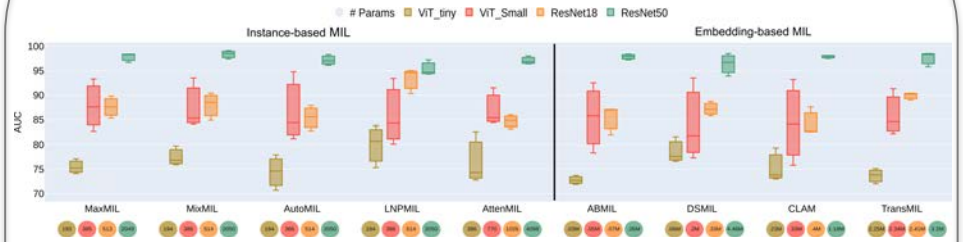
Learn « how to refine »

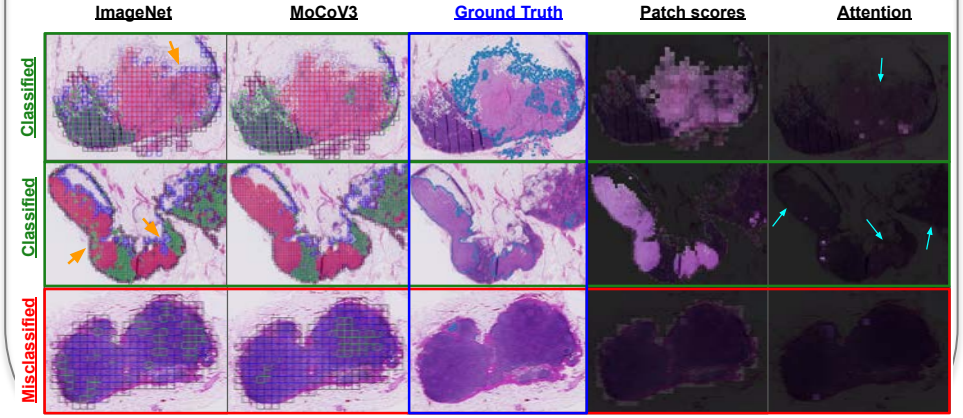



## Simple & Interpretable MIL methods for Diagnosis

Gori. ECCV '24 (under review)

segmentation H&E WSI



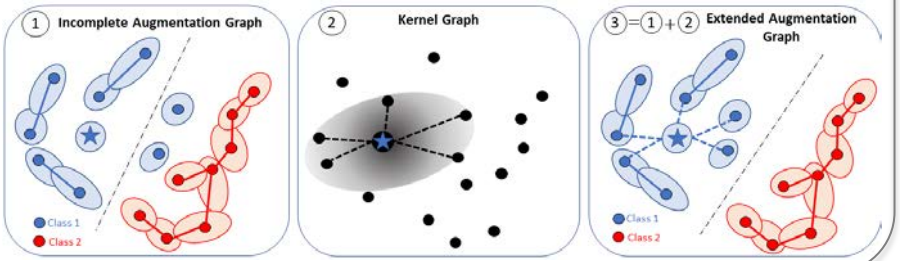



# Generic Methodological ML Approaches

➔ Fair AI

## Integrating Prior Knowledge in Contrastive Learning with Kernel

Gori.ICML'23




## Separating Common from Salient Patterns

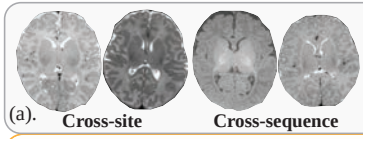
Gori. ICMLW '23
ICLR' 24
AISTATS'24


Data Bias

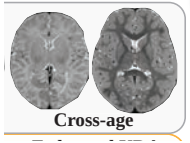
Open-access cohorts

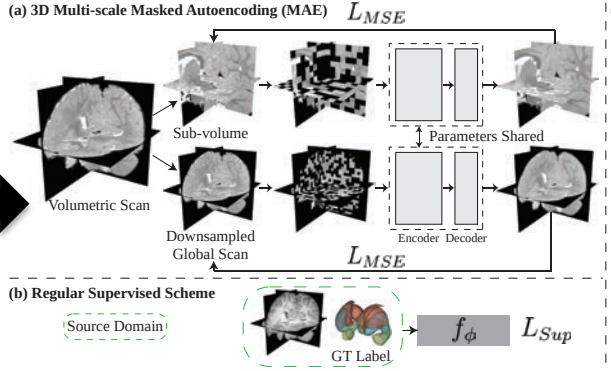
## MAPSeg: Unified Unsupervised Domain Adaptation for Heterogeneous Medical Images Segmentation Based on 3D Masked Autoencoding and Pseudo-labeling

Angelini. CVPR'24




Domains adaptation needs

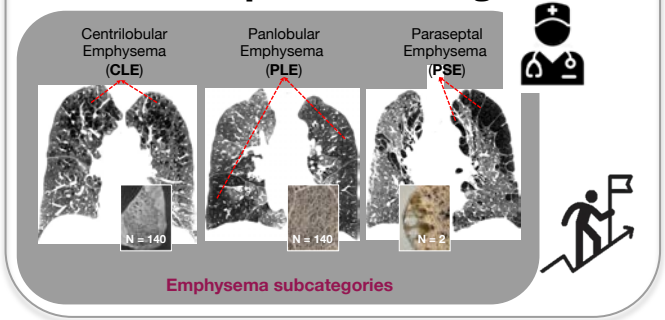


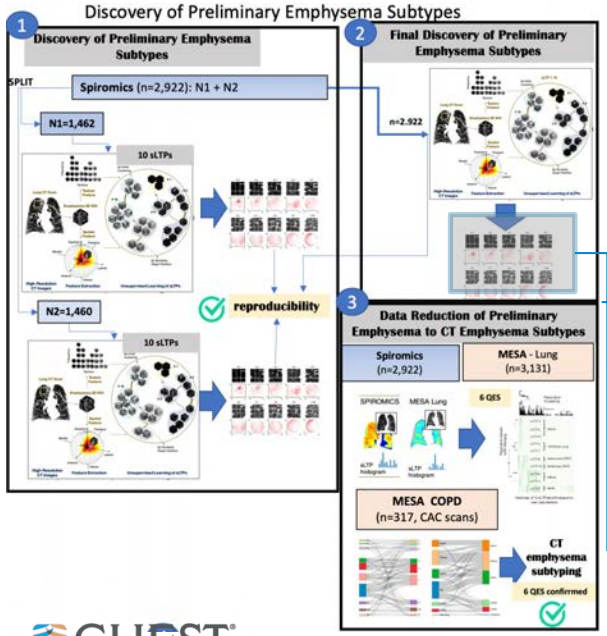
# 4.a Machine Learning on VERY Large cohorts

**Unsupervised Learning of <u>emphysema</u> subtypes on lung CT scans**

➔ **Very large cohorts + no annotations = unsupervised learning**

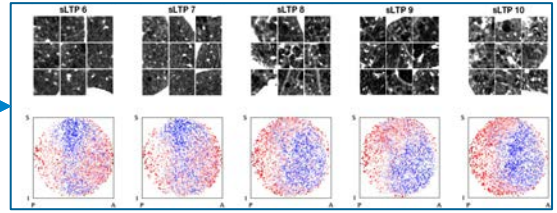



➔ New therapies
➔ Personalised medicine










CHEST

Pulmonary emphysema subtypes defined by unsupervised machine learning on CT scans

Elsa D Angelini,[1,2,3] Jie Yang,[1] Pallavi P Balte,[4] Eric A Hoffman,[5] Ani W Manichaikul,[6] Yifei Sun,[7] Wei Shen,[8,9] John H M Austin,[10] Norrina B Allen,[11] Eugene R Bleecker,[12] Russell Bowler,[13] Michael H Cho,[14,15] Christopher S Cooper,[16] David Couper,[17] Mark T Dransfield,[18] Christine Kim Garcia,[4] MeiLan K Han,[19] Nadia N Hansel,[20] Emlyn Hughes,[21] David R Jacobs,[22] Silva Kasela,[23,24] Joel Daniel Kaufman,[25] John Shinn Kim,[4,26] Tuuli Lappalainen,[23] Joao Lima,[20] Daniel Malinsky,[7] Fernando J Martinez,[27] Elizabeth C Oelsner,[4] Victor E Ortega,[28] Robert Paine,[29] Wendy Post,[20] Tess D Potting, Edwin K Silverman,[14] Benjamin M Smith,[4,31] Prescott G Woodruff,[33] Andrew F Laine,[1,9,10]


JAMA | Original Investigation

Association Between Long-term Exposure to Ambient Air Pollution and Change in Quantitatively Assessed Emphysema and Lung Function

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IF = 56

TELECOM Paris

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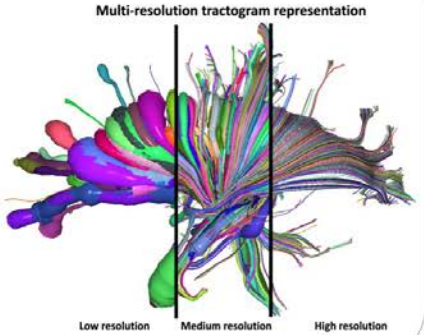
2,4

# Clinical applications & impact

## Modeling medical knowledge and anatomy

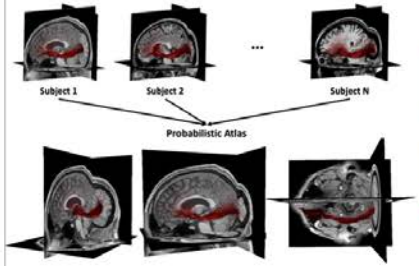


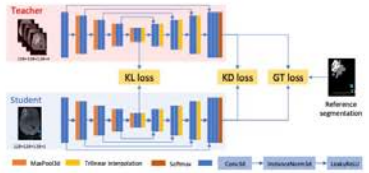

Gori. ISBI'19
Gori. EG VCBM '18
Gori. MedIA '17

➔ New therapies,
➔ Digital Twin

## Transfering medical representations

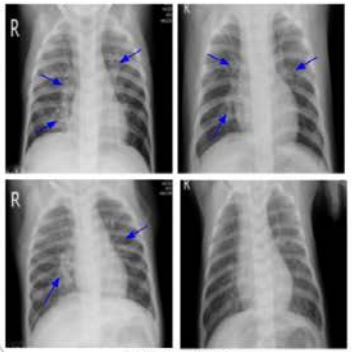
Gori. MICCAI' 20, '21

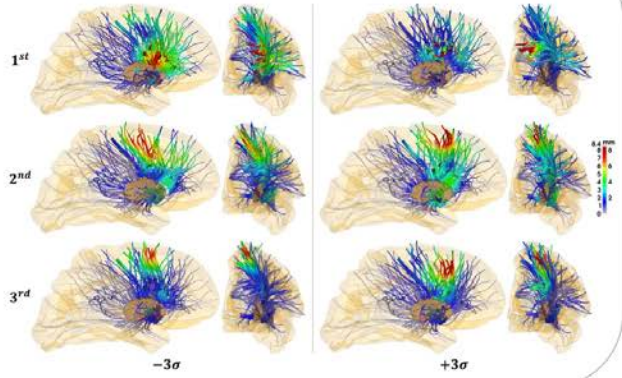



➔ Limit number of scans
➔ Improve diagnosis

## Discovering medical biomarkers




Gori. ECML '21
Gori. IEEE TMI '16, '18
Angelini. Chest'23
Angelini, JAMA'19

➔ Quantitative Diagnosis
➔ Personalised medicine

# ➔ Our vision for tomorrow

**Upstream research topics:**
- ML in low-annotations regimen
- ML on multi-omics data for **Cancer**
- Full 3D exploitation of images
- Frugal AI

**As a community:**
- Large Foundational Models (SAM for medical images)
- Robust & Fair & Open AI
- Multi-modal open cohorts (cf PSCC)

**➔ Industrial partners needed for:**
- Phd CIFRE fellowships
- Chairs
- Sponsoring Data Challenges for our students
- Contributions to MSc courses and use-cases

PARIS-SACLAY CANCER CLUSTER
FRANCE INNOVATION CANCER

IP-Paris is a founding member of the **Paris Saclay Cancer Center**
(https://www.parissaclaycancercluster.org/)

**+ PSCC Connect Association**

INSTITUT POLYTECHNIQUE DE PARIS
E4H
ENGINEERING FOR HEALTH INTERDISCIPLINARY CENTER

**"Engineering for Health" IP-Paris Center**

**+**

Hi! PARIS
PARIS ARTIFICIAL INTELLIGENCE FOR SOCIETY

**1st PSCC-IPParis Medical Data Challenge on "AI for Lung Cancer Imaging"**

SPONSORS WANTED

**Feb 2024**