UCLouvain
icteam
Institute of Information and Communication Technologies, Electronics and Applied Mathematics

Coalitonal active learning

« Providing the benefits of Deep Learning advances for all patients »

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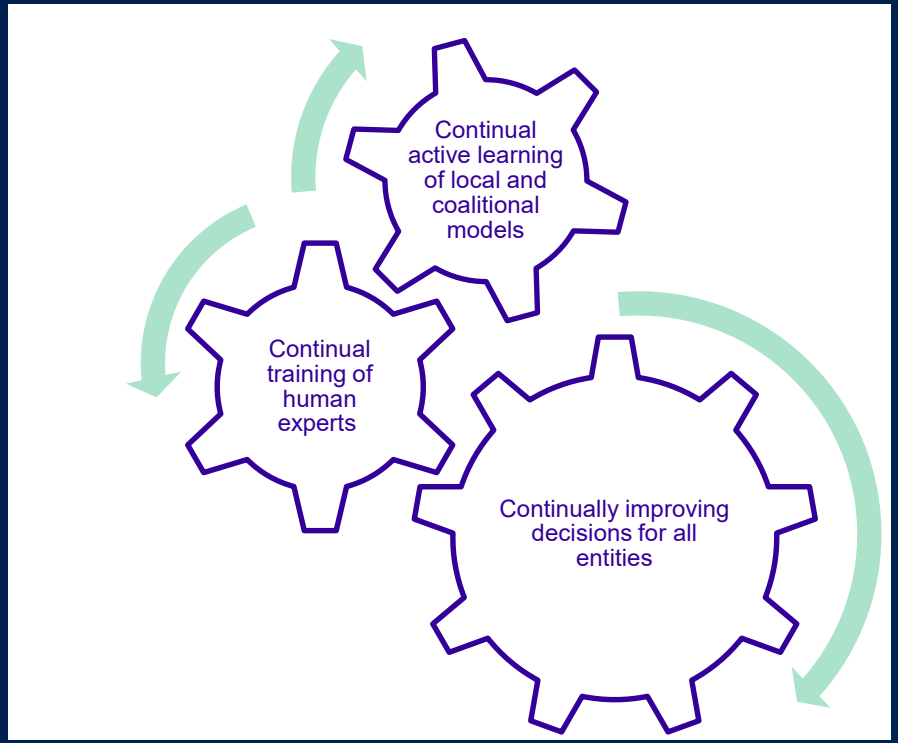
Scaling up the adoption of **deep learning** in **clinical practice !**

An AI divide appears with non-teaching hospitals in particular lagging behind!

The clinical decision in a coalition of hospitals



-Hospitals sharing the same ways of caring (mindlines)

-Engaged in a peer-review system: anonymous annotations can be requested to any expert by the coalition and be peer-reviewed

-Clinical decisions are resulting from integrating humans, local model and coalitional model

Coalitional active learning New paradigms

- Federated learning:
  - From privacy motivations to the sharing of best practices
- Active (continual) learning
  - From parcimonuous human annotations to a human-AI co-learning (the most informative cases are used for experts continual learning)

The context: Image-based decision systems

1) Radiotherapy/Protontherapy

- Complex compromizes to achieve (protection of organs at risk, i.e. secondary effects)

  -> Need for **multi-expert** decisions from images

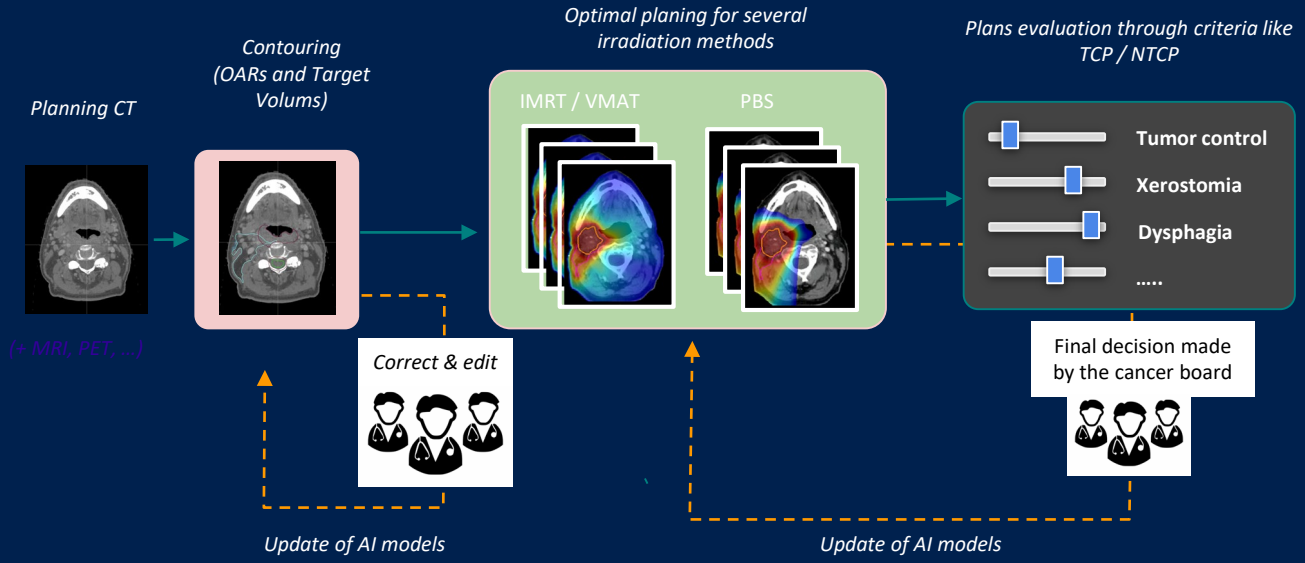
2) Cancer screening and diagnosis

- development of new biomarkers from cellular models to reduce false positives

  -> **continual learning** and double advices

DATA -> PREDICTION -> DECISION

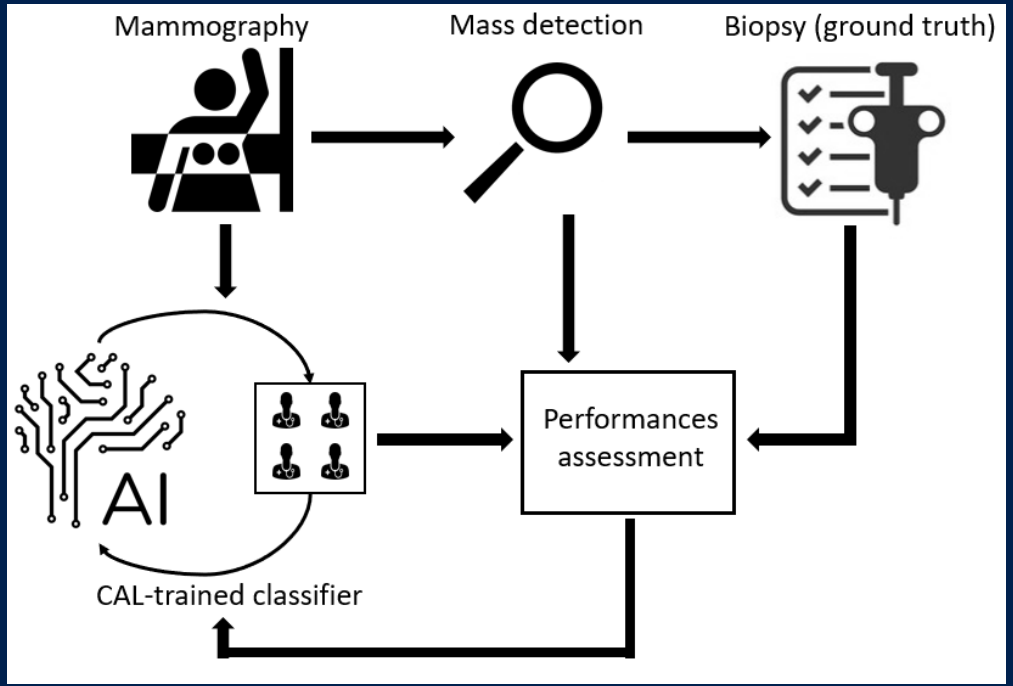
Optimal treatment planing in protontherapy requires multi-expert decisions for the best compromizes



DATA -> PREDICTION -> DECISION

No direct outccome

Improved screening of breast cancer through continual learning of models



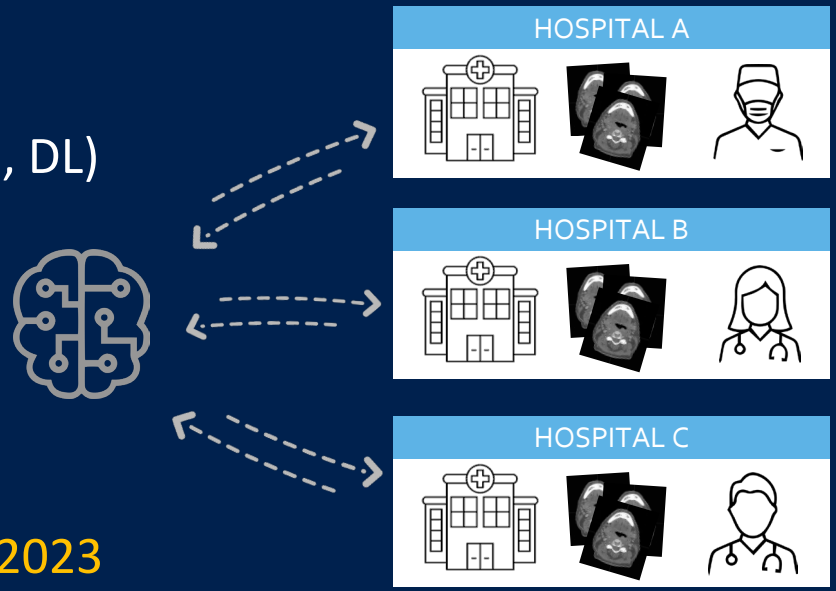
Outcome available
for positives (true and false)

Goal: reducing false positives

A brief over Federated Learning

- Well mastered domain
  - Theoretical proofs (SVM, DL)
  - How to manage heterogeneous data
  - How to manage heterogeneous labels

Call for the CVPR workshop 2023

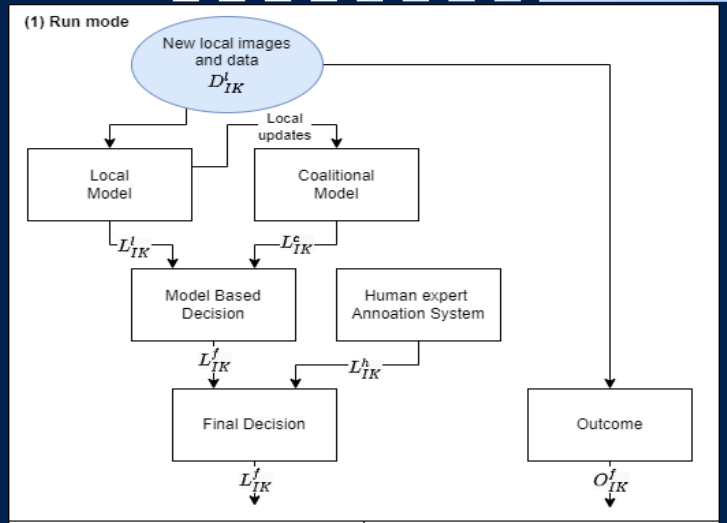


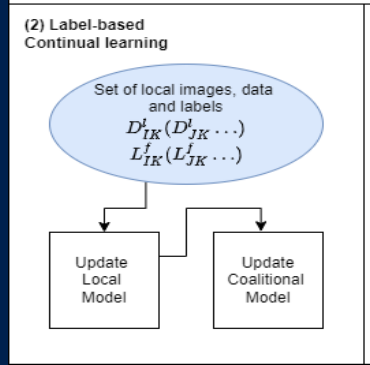
-Boyd, S., Parikh, N., Chu, E., Peleato, B., & Eckstein, J. (2011). “Distributed optimization and statistical learning via the alternating direction method of multipliers”. Foundations and Trends® in Machine Learning, 3(1), 1-122

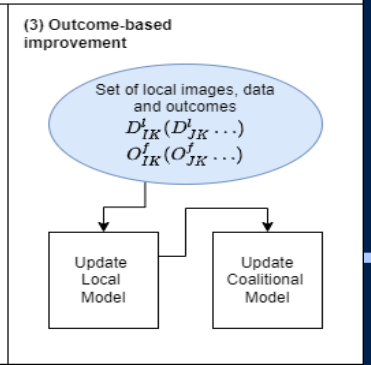
Coalition definition

- An ensemble of experts belonging to a network of hospitals sharing the same way of caring (mindlines)
- Engaged in a federated learning process : the coalitional model is learned by travelling from hospital to hospital
- Engaged in a peer-review system: anonymous annotations can be requested by the coalitional model (active learning) from any expert of the coalition and be peer-reviewed
- Clinical decisions are resulting from consensus between humans, local model and coalitional model

Combining local and coalitional models- update by human labels and/or by outcomes







Starting from a global (fondation ;-)) model

Fine-tuning by supervised learning
- -at the coalitional level (federated)
- -at the local level (non-federated)

Local: fine tunijng on local coditions but bias
Global: gain in data sets and annotation availabilities

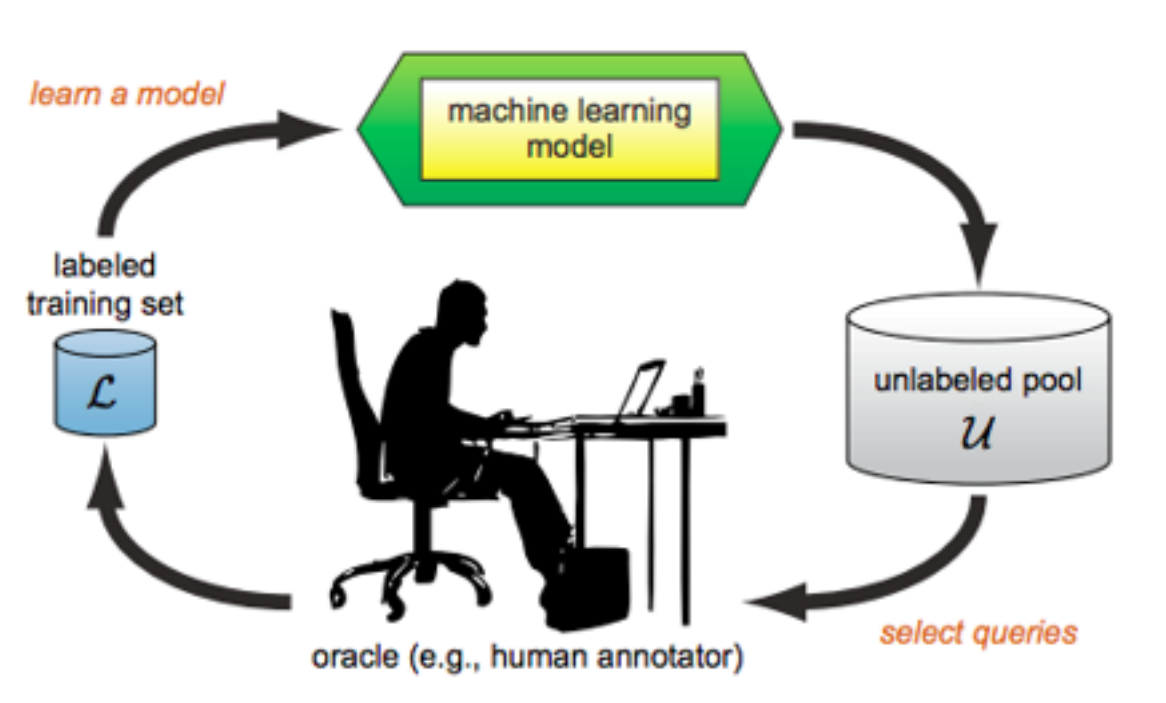
-Convergence of the 2 models: common practices
-Coalitional gain
-Learnability

A brief over active learning

Annotations

Intelligent selection

An iterative process

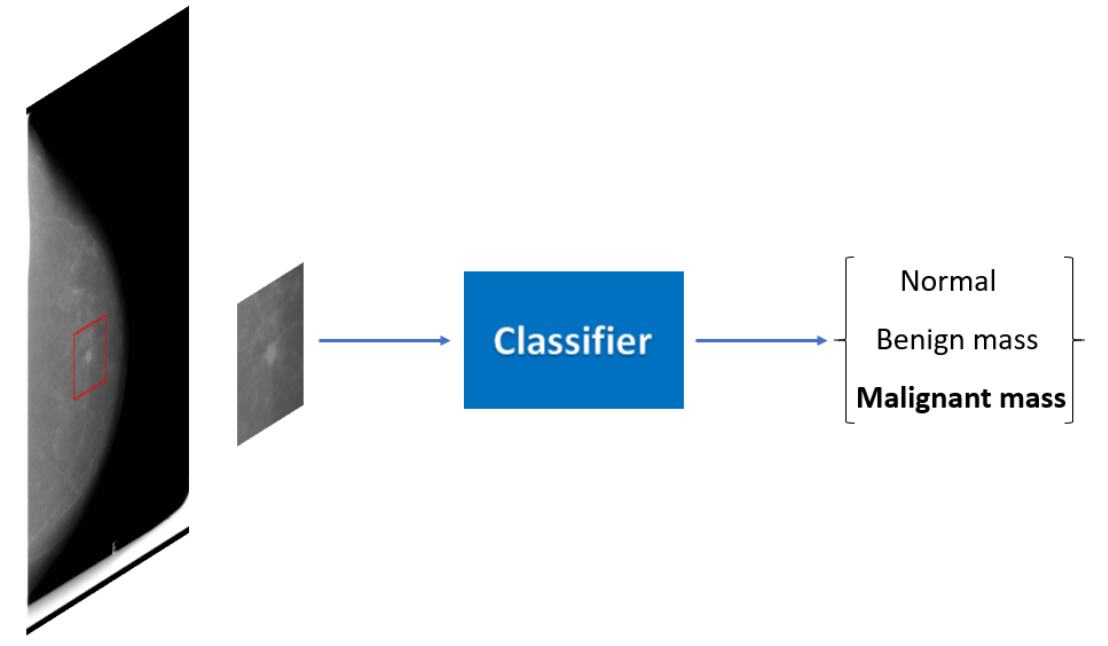


Three methods

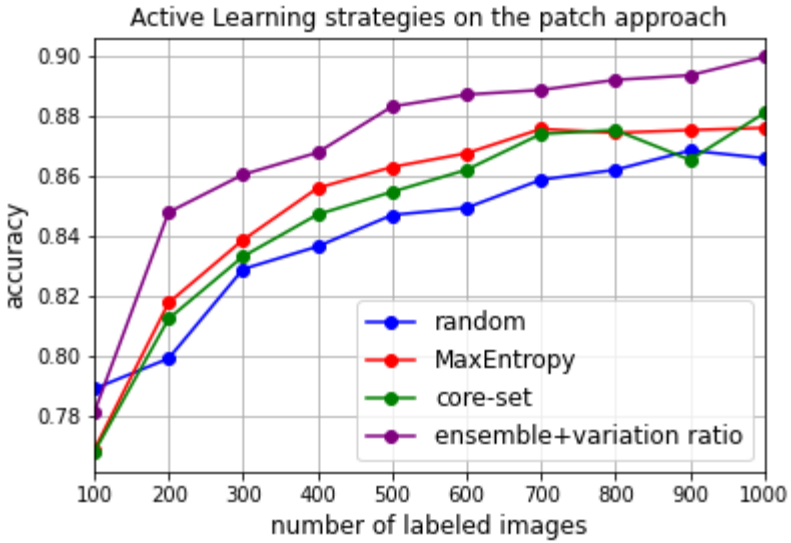
- **Uncertainty (shake the model)**
- **Diversity (measure distances)**
- **Query-by-committee (agreement between competing models)**

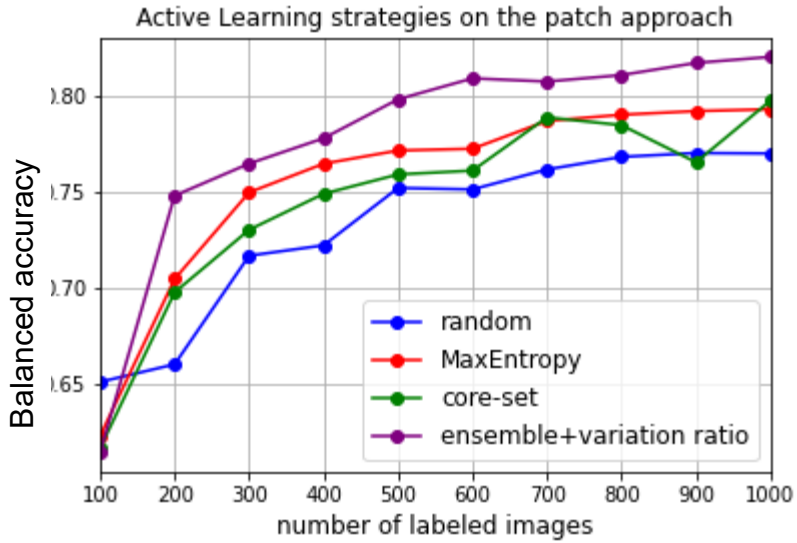
Active Learning in Mammography

Resnet 18 (global and patch based)



Active Learning in Mammography





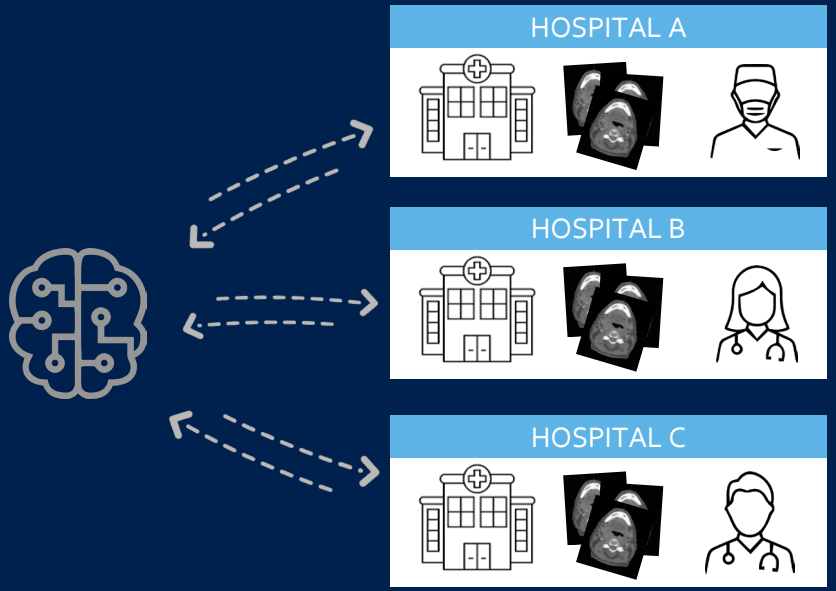
Shift toward the learning value of the to-be-annotated cases

SCALING

Securing Coalitional Active Learning for medical imagING

Medical practice is continuously improved by the progresses of Science and by new Data

Continuing Medical Education (CME) and second advice in a coalition



SCALING

Securing Coalitional Active Learning for medical imagING

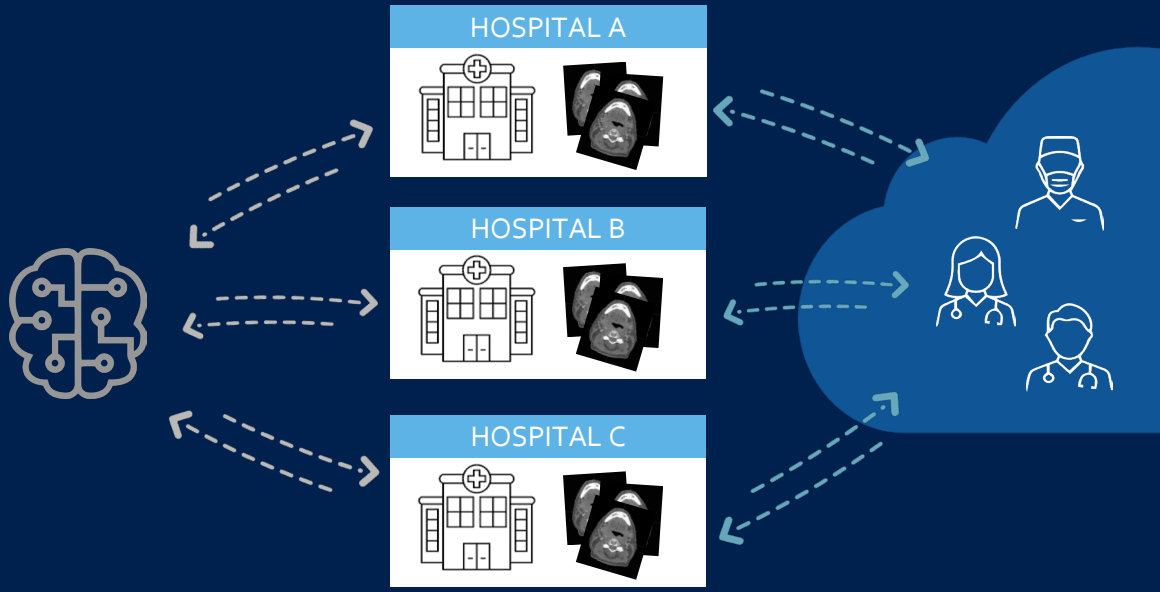
Medical practice is continuously improved by the progresses of Science and by new Data

Continuing Medical Education (CME) and second advices in a coalition

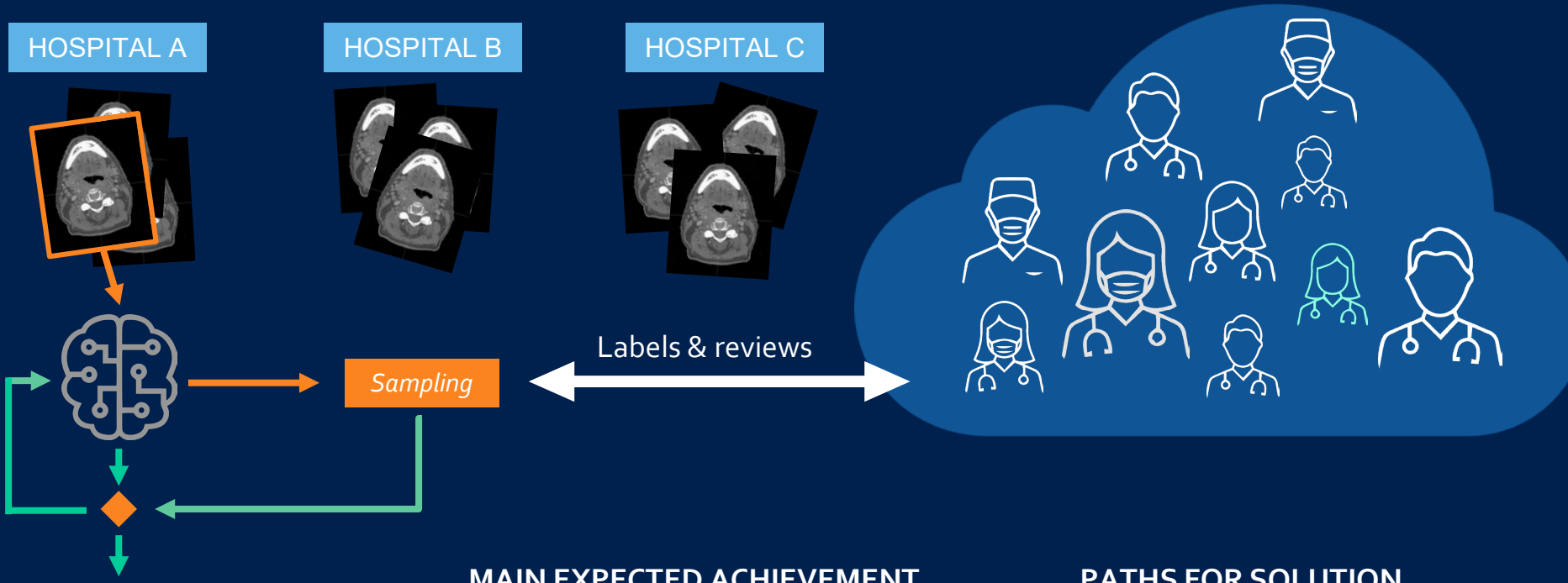
A **coalitional active learning** uses **labels provided by a coalition**

AI **and** human expertise are continuously improving together

to align members on **common best decisions**



New criteria and optimisation procedures



- ✓ Proposal for clinical decision
- ✓ Confidence

MAIN EXPECTED ACHIEVEMENT

- ✓ Join optimisation model - human expertise under limited time budgets

PATHS FOR SOLUTION

- ✓ Coalitional gain & optimum sampling
- ✓ Reinforcement learning

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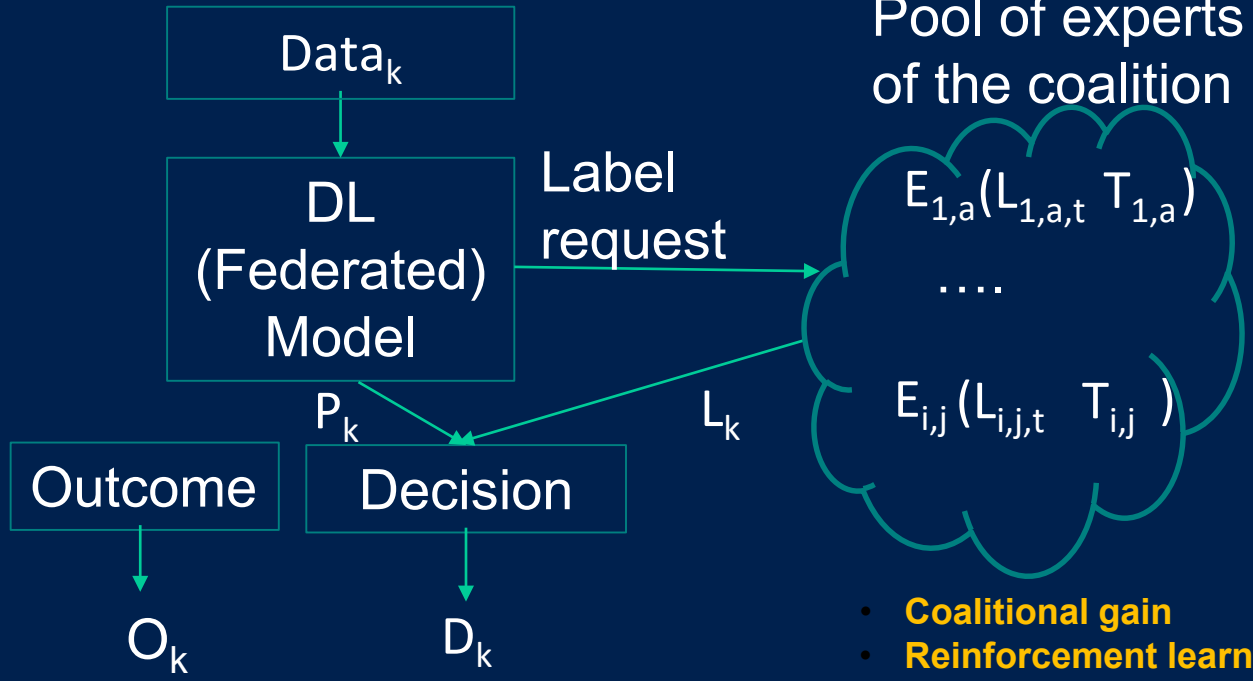
Multi-experts query for label: example of procedure

- Ask for an expert label (contour, classes, …) on image
- If the label differs strongly from the model outcome, ask a second expert label
- Ask a 3d expert to vote between the 2 labels
- Grant a token to the 3 experts
- Update the expert level of the picked expert
- Optimize the time budget of N experts denoted k each with an expertise level Lk and an available time Tk

Active Learning of Model and Experts



Seed: Optimal Intermittent Particle Filter, IEEE Trans on Signal Processing (2022)

- **Coalitional gain**
- **Reinforcement learning strategy**
- **Sampling an evolutive system**

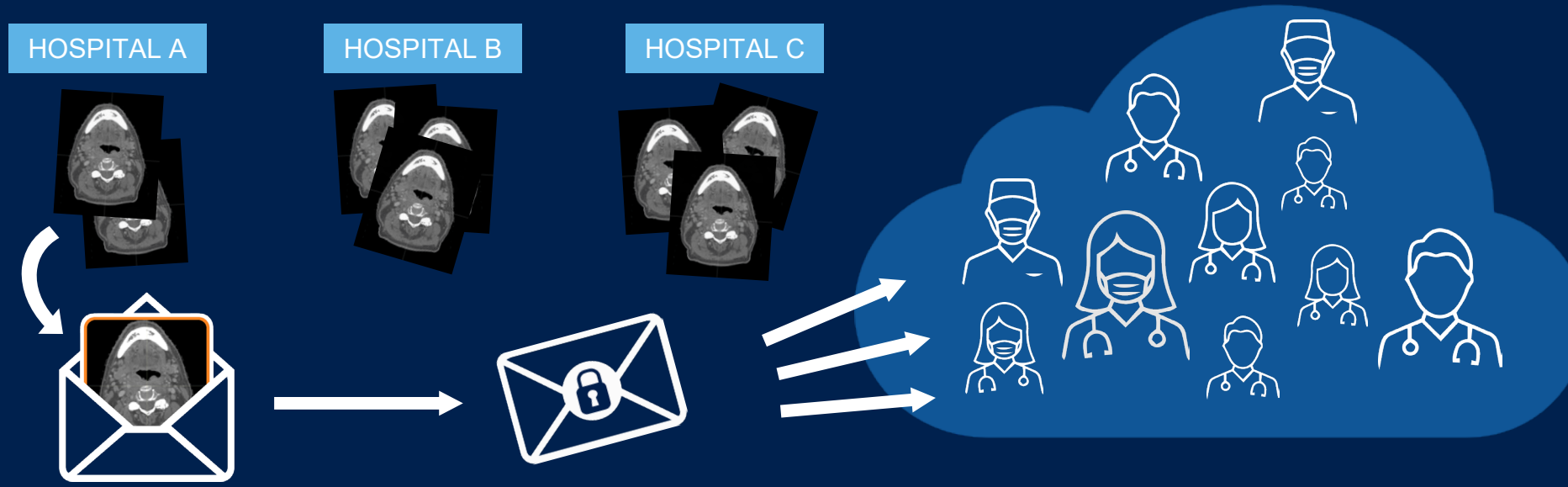
A dynamic model of the expert

- Slow decrease in time
- Steps per treated cases
- Optimisation under time budget
- Stochatistic scheduling (broader than multi armed-bandit)

Coalitional gain

- Cooperative game theory (Shapley)
  - The size of a stable coalition
  - The reward model

Functional models and security tools

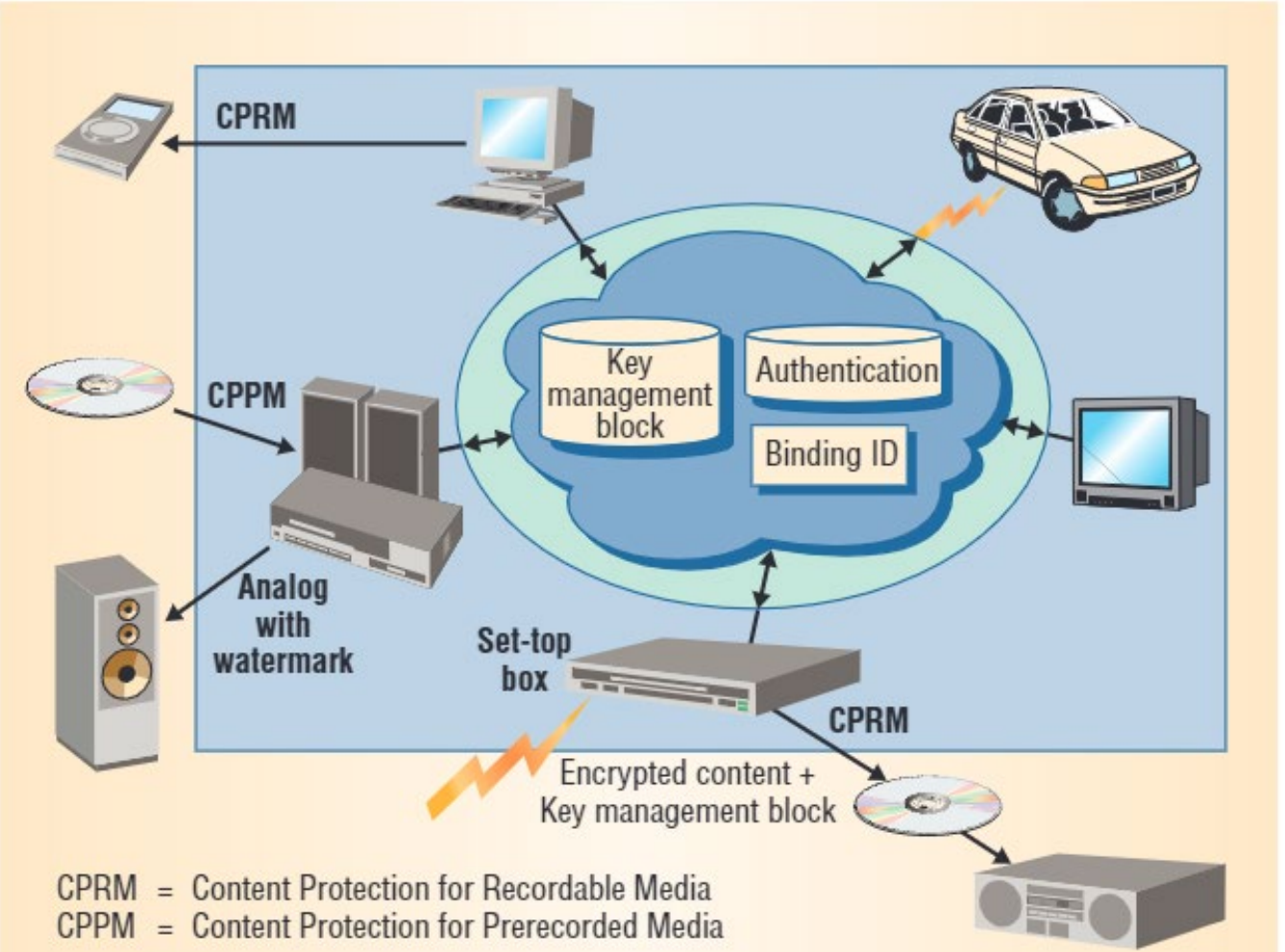


EXPECTED ACHIEVEMENTS

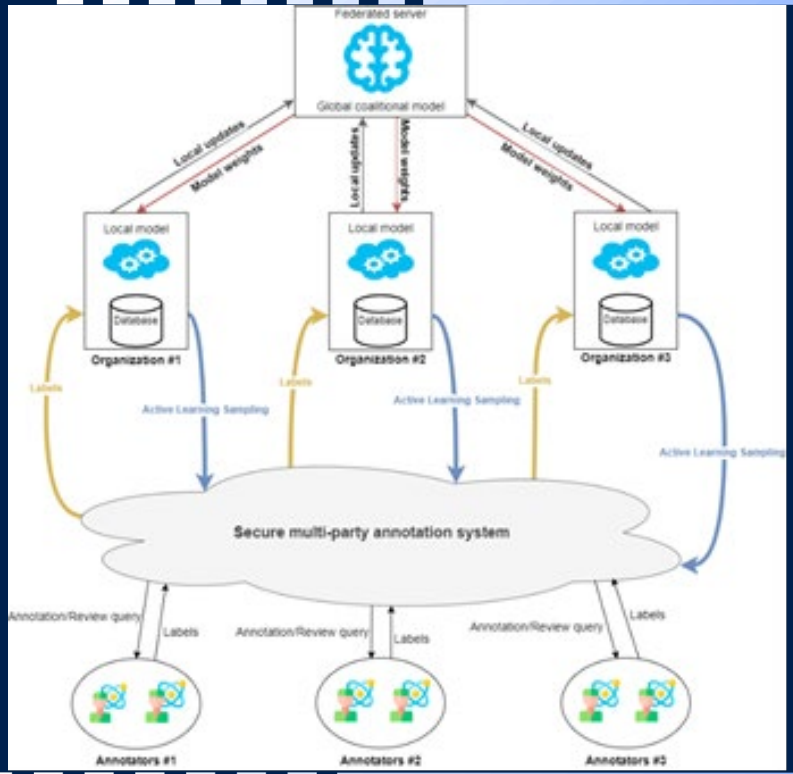
- ✓ Secure Multicast
- ✓ Ephemeral use of patient data
- ✓ Tokenization and Anonymity of labels

PATHS FOR SOLUTION

- ✓ Functional model
- ✓ Conditional access
- ✓ Watermarking (read once, fingerprinting)


CPRM
CPPM
Key management block
Authentication
Binding ID
Analog with watermark
Set-top box
CPRM
Encrypted content + Key management block
CPRM = Content Protection for Recordable Media
CPPM = Content Protection for Prerecorded Media

Coalitional active learning: our graal!



Coaltional Active Learning is a dynamic system

- In support of continually improving decisions for all
- In support of a continual education of experts

SCALING will provide

- Optimal coalitional gain
- Coalitional learnability
- Consensus for decision
- Human time budget bounds
- Incentivisation
- Trustworthy annotations

Clinical decisions need a better connection with clinical pratice

- From a multidisciplinary team work
- From (sometimes) subjective clinical assessment
- From MD who are continuously improving their expertise through
  - Continual Medical Education
  - Peer reviews (second or third advice)
- From signals which are continuously improving through progresses of medical devices
- From a medical practice linked to an healthcare system (Mindlines vs Guidelines)

IMPACTS FOR EUROPE AND BEYOND

- New research topic that focuses on trusted AI for coalitional improving decision
- A new implementation approach of Deep Learning adapted to the variety of the European clinical practices
- Continuously improving clinical decision in the coalition
  - Reducing false positive and biopsies in breast cancer screening
  - Improving choices for radiotherapy treatments including proton therapy

Test and Experimentation Facilities
Key opinion leaders in radiotherapy and cancer screening