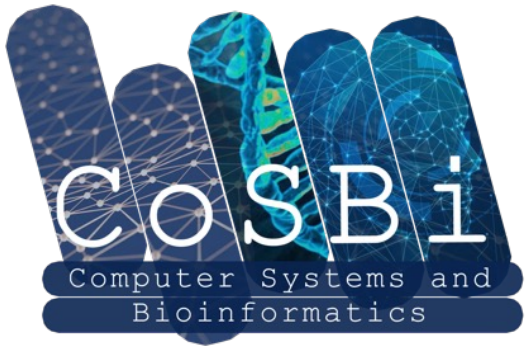
Building an AI-Enabled Metaverse for Intelligent Healthcare: Opportunities and Challenges



Ital-IA 2023
AI per la Medicina

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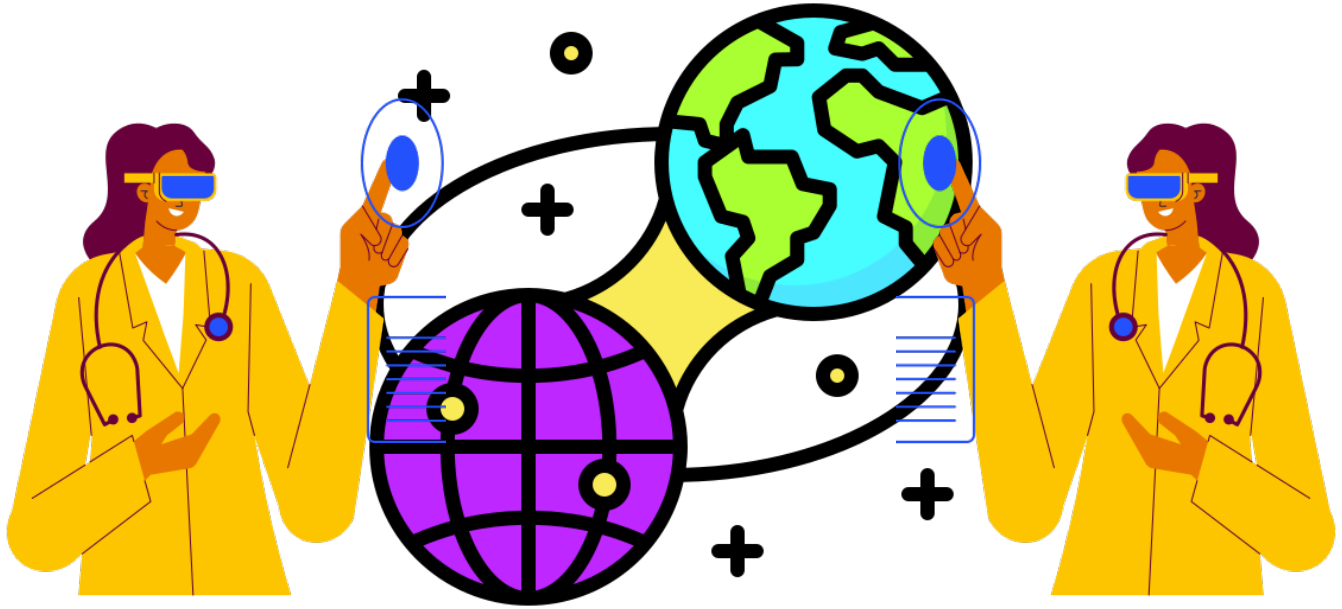
Metaverse

- **Virtual environment** where healthcare professionals, patients, and researchers can **interact and collaborate** using **digital technologies**.
- In **healthcare**, the metaverse can be used to **improve** the **efficiency and effectiveness** of healthcare **services**, as well as provide **new opportunities** for **research and innovation**.
- It **requires** a range of **technologies**, including **AI**, which can be used to create **realistic simulations of healthcare scenarios**, **analyze patient data**, and **provide personalized recommendations**.



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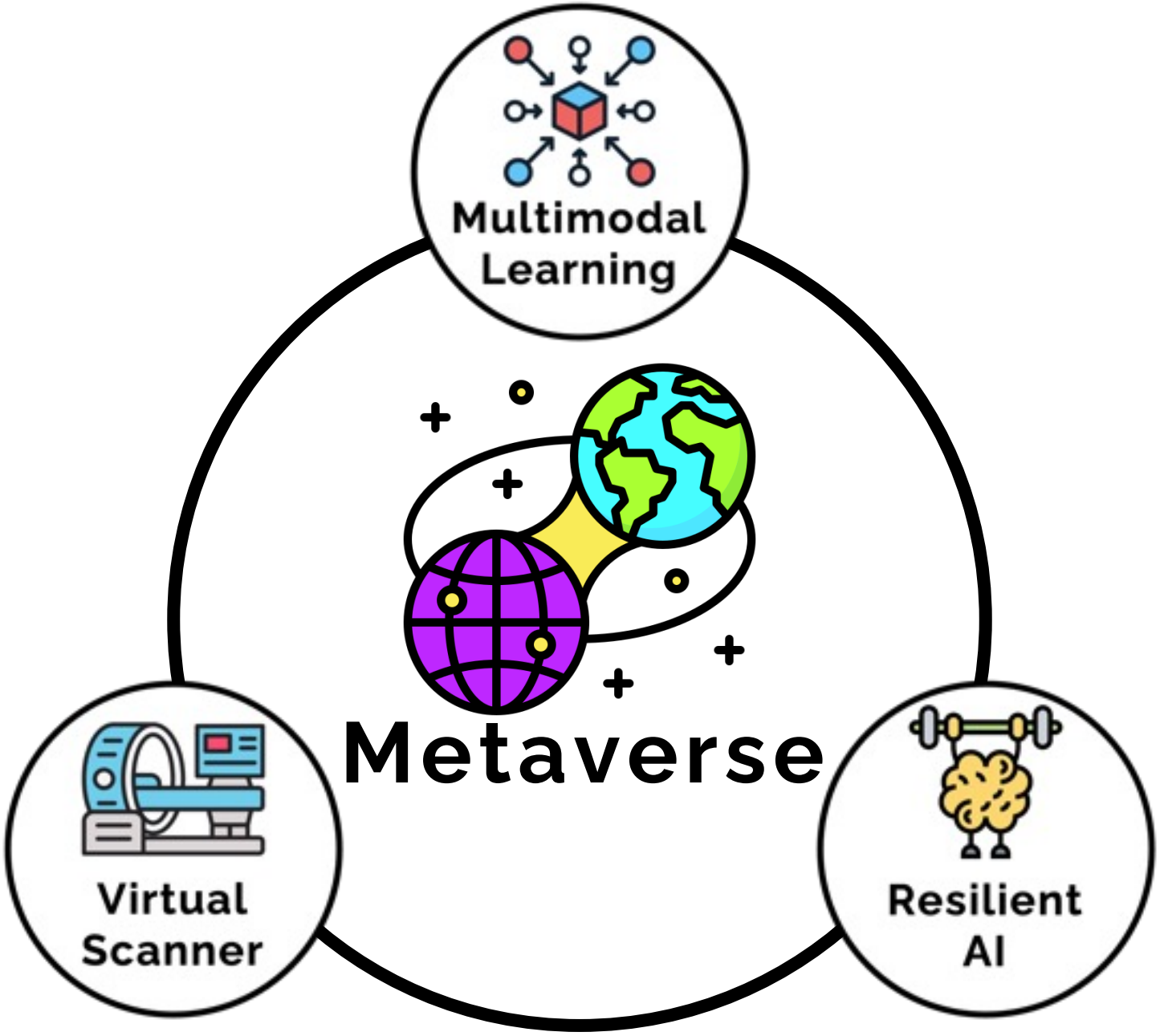

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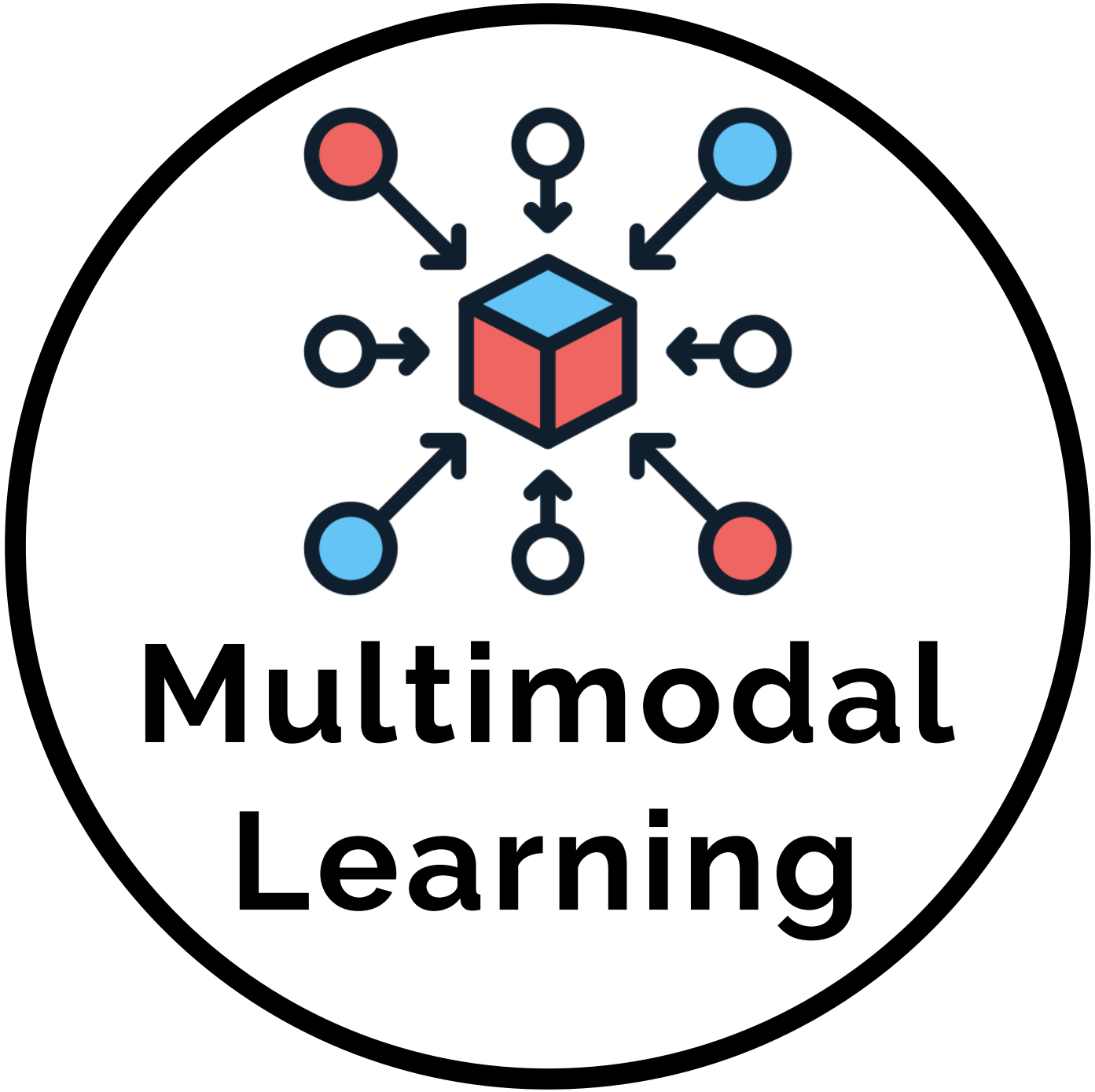
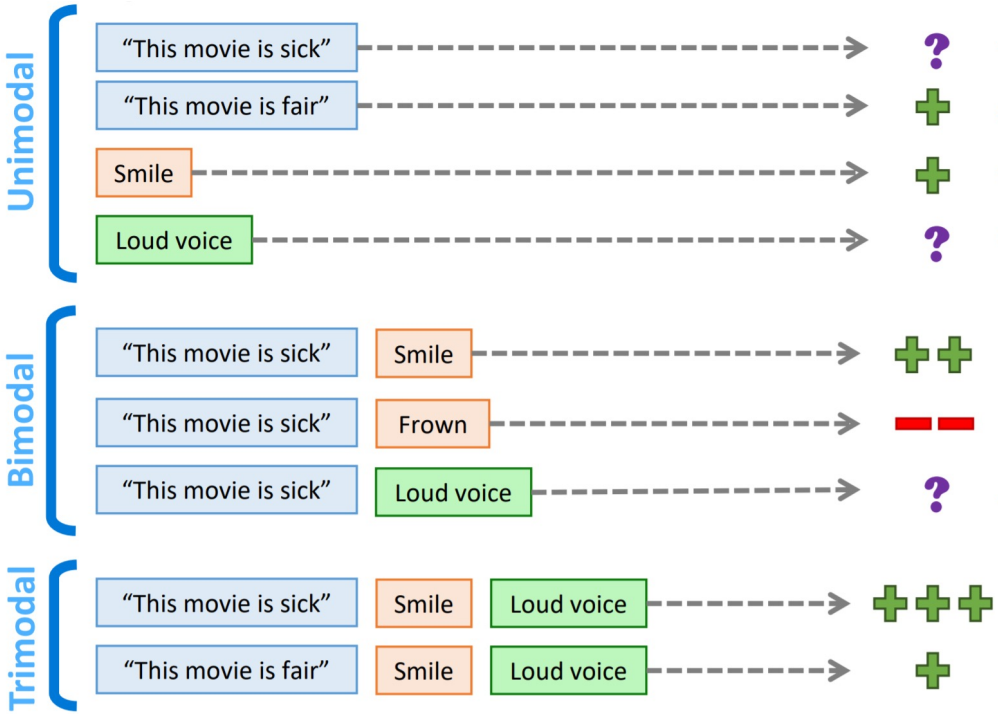

Multimodal
Learning

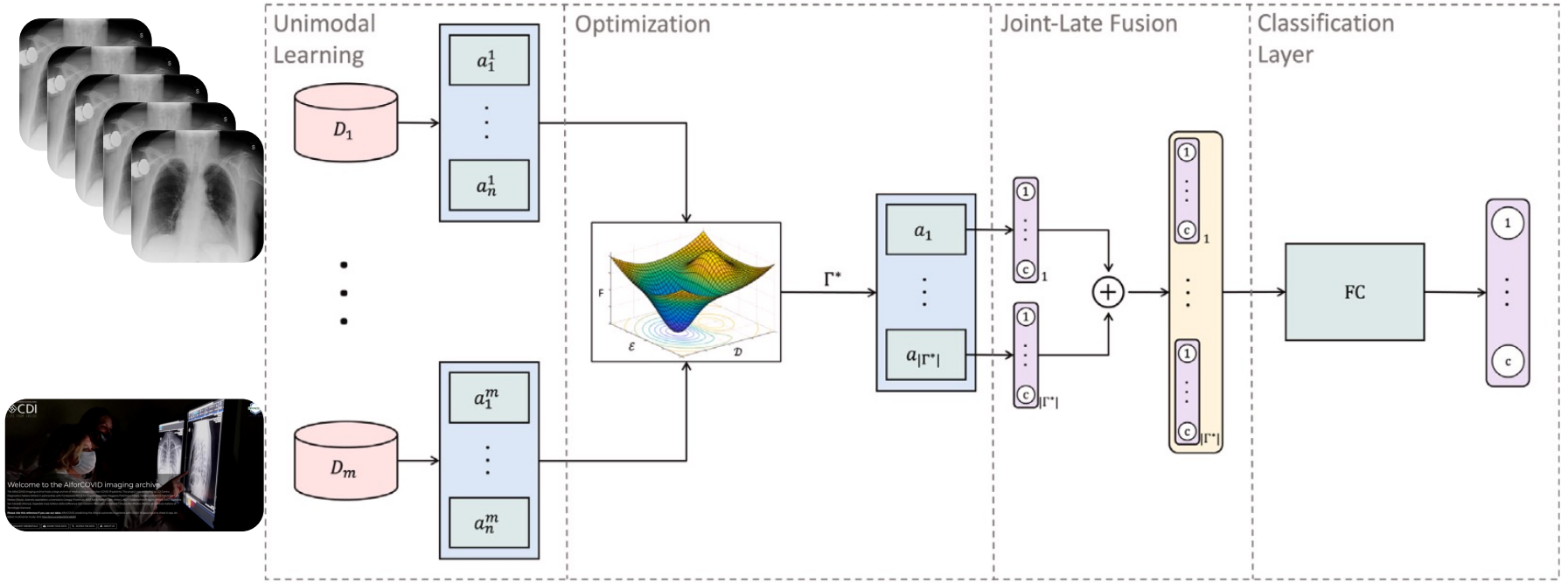
Multimodal Learning

- **Multimodal learning** involves the integration of **heterogeneous** data from **multiple sources** extracted from the observation of the same phenomena or problem.
- The use of multimodal data sources allows the extraction of a **complementary**, **more robust** and **richer data representation**, with the **aim of improving performance compared to the use of a stand-alone modality**.



When, How and Which?

- **When**: At which level should the modalities be fused?
  - **Iterative algorithm** that increases the number of fusion connections.
- **How**: How should the modalities be fused?
  - **Optimizing** the setup of a **multimodal end-to-end model**.
- **Which**: Which modalities should be fused? Which models?
  - **Multi-objective** optimized **ensemble search**.

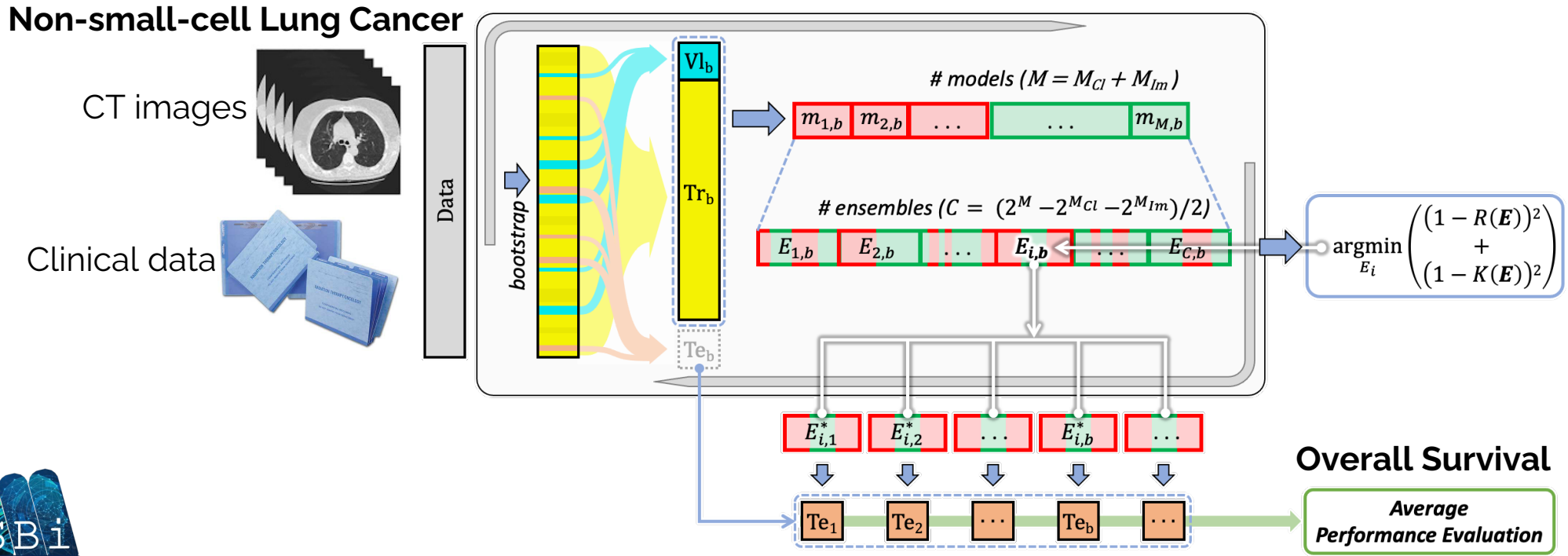


Mild

Severe

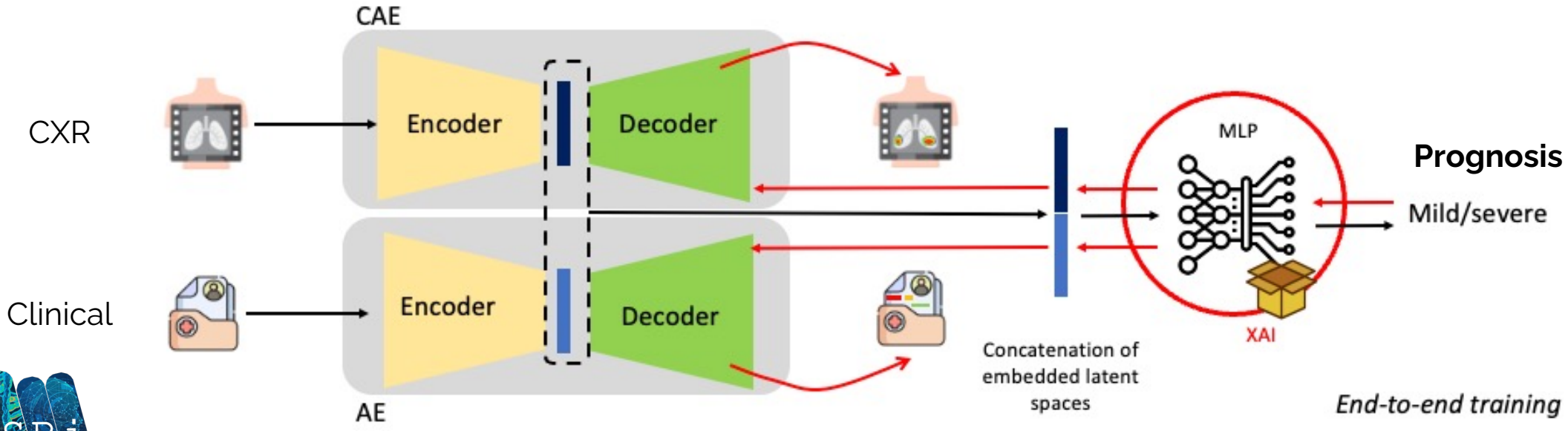
Multimodal Ensemble for Overall Survival

- In a classification task it is hard to understand **a priori** which classifier is **best suited** to obtain good results.
- A **typical workflow** would be to test multiple classifiers and then choose the single classifier which performs the best on a validation set, or combining all of them.
- **Goal**: Find **optimal set of classifiers** whose aggregation obtains better performance than any single classifier.



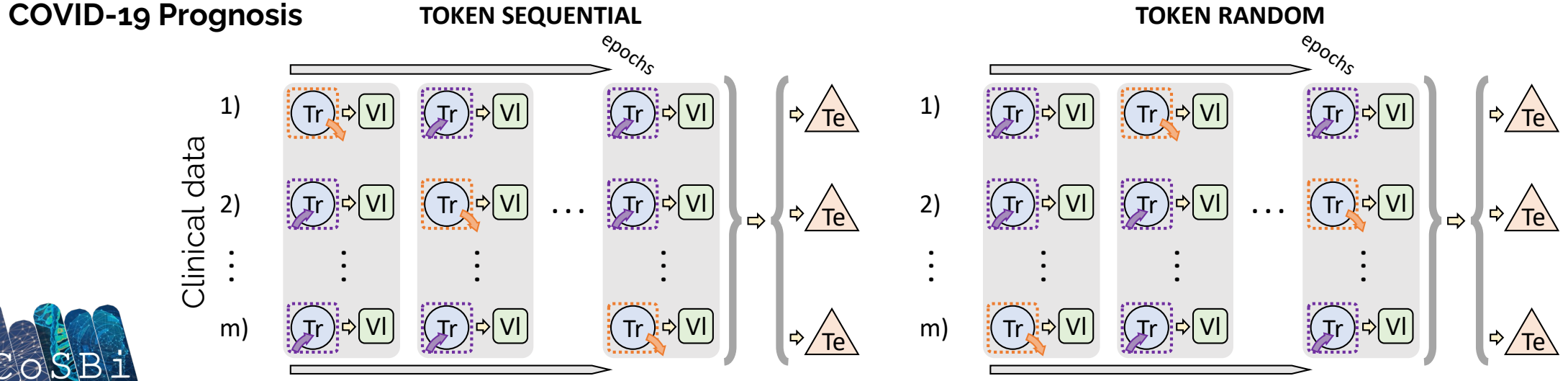
Multimodal XAI

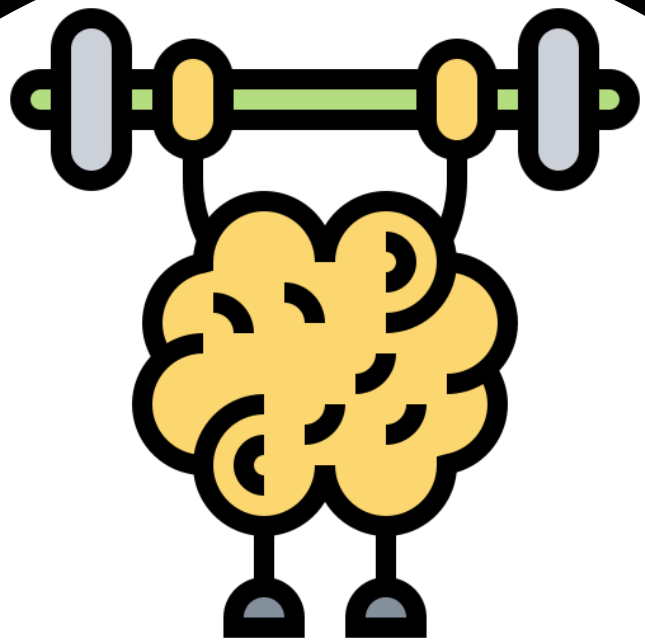
- The major **disadvantage** of DNNs is their **lack of interpretability**:
  - **XAI** produces information to make a **model's functioning** clear or easy to understand.
  - The literature is well advanced for **unimodal models** but it **lacks research for MDL**.
- **Goals**:
  - Illustrate the **reasoning** behind the decisions taken by the model.
  - Show the relative **contribution of each modality** in making the decision.



Federated Learning

- **Sensitive patient data** must be protected to avoid **privacy violations**.
- To address this issue, **federated learning** has emerged as a potential solution.
- **New paradigm:** a **token** is passed in each epoch **sequentially** or **randomly** among the clients, which is intended to allow the weights to be sent to the server only by its owner.
- **Eliminating the role of the server** and **halving the number of parameters** sent in each round.

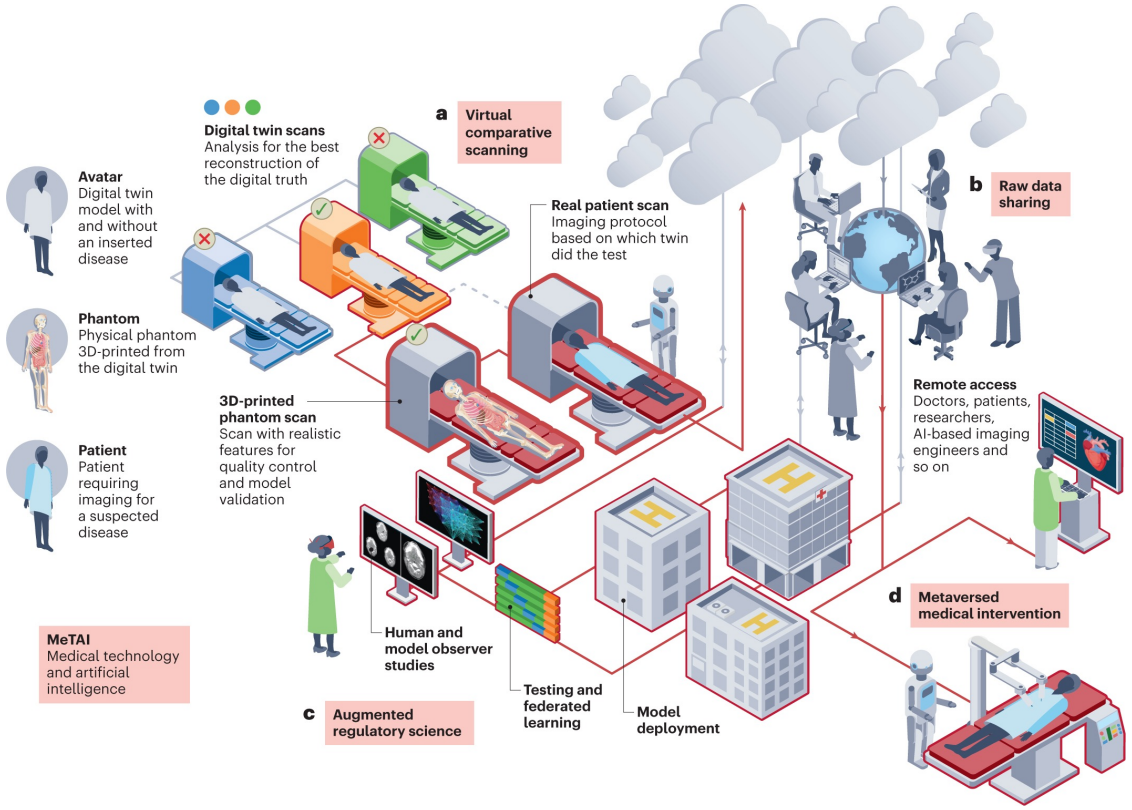




Resilient AI

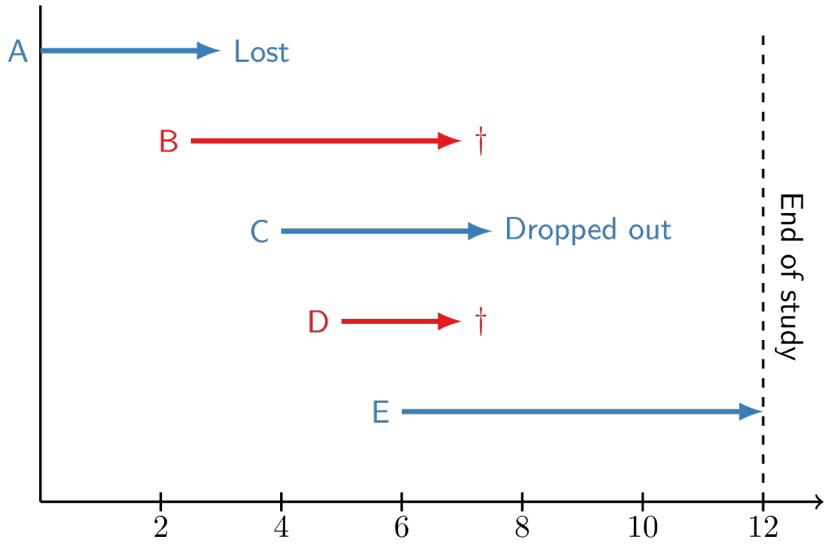
Resilient AI

- In healthcare, **unstructured**, **noisy**, **incomplete**, **limited in number**, or **partially inconsistent data** is a significant challenge.
- In **AI**, such situations could impact models' **accuracy** and **reliability**, leading to **incorrect** or **biased outcomes**.
- Developing **resilient AI systems** able to handle such types of data is **crucial** in a Metaverse for Intelligent Healthcare.

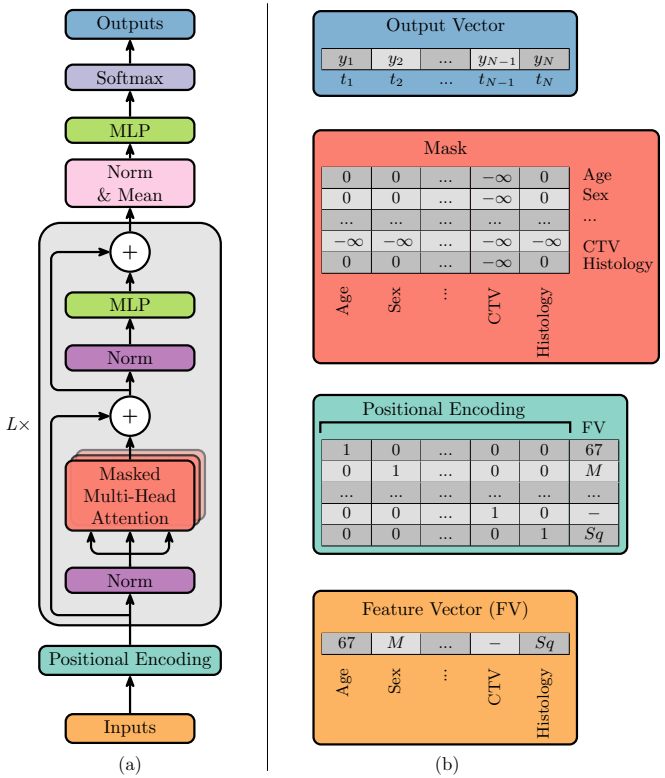


Missing Features

- **Missing data** is a common problem in healthcare datasets, occurring when some information is not available for some patients or variables in a dataset.
- Missing data not only could **bias the results**, but it often contrasts with the needs of **AI models**, which often **require complete data** to function properly.



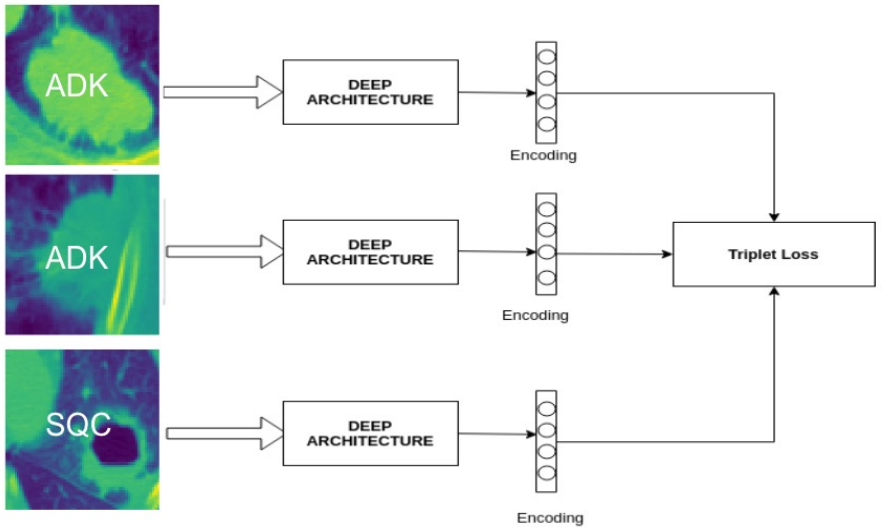
Non-small-cell Lung Cancer Overall Survival

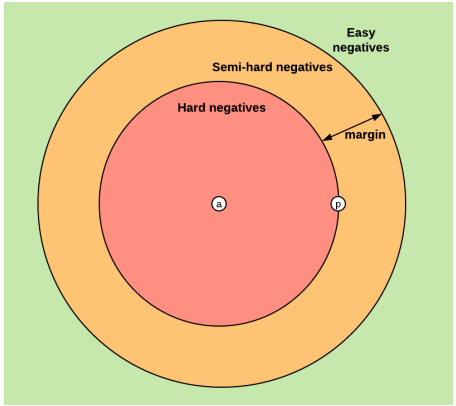


Transformer model **masking** in the self-attention module the **missing features**.

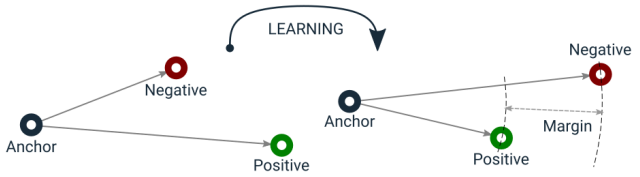
Siamese Networks

- It is well known that the AI's power of analyzing **vast amounts of data** is an element lying behind models' performance.
- **Data availability** is a major barrier in many domains, healthcare and metaverse included.
- To overcome this limitation, **Siamese networks** are a viable alternative, which utilize **inter-class diversities** and **intra-class similarities**, augmenting the **number of instances** (triplets).



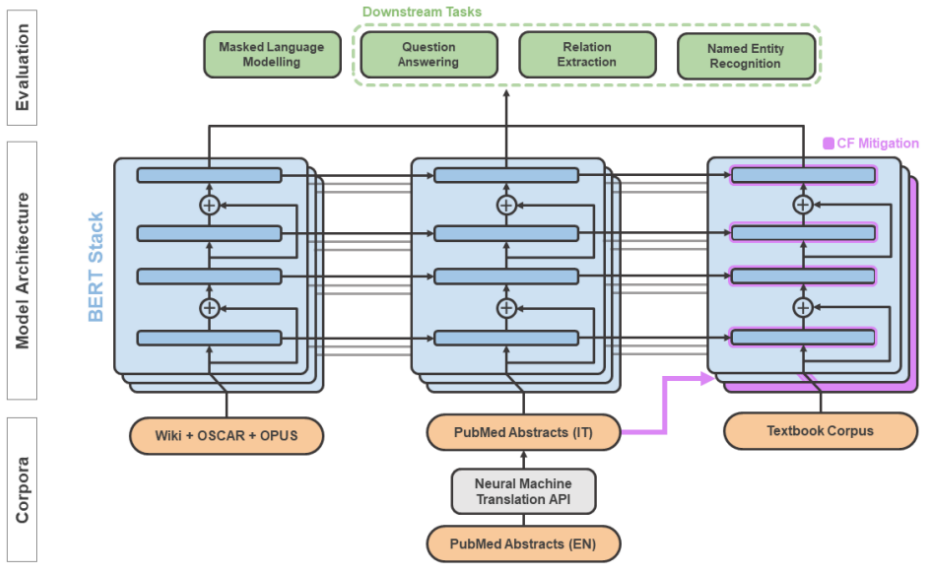


$$Loss = \sum_{i=1}^{N} \left[\|f_i^a - f_i^p\|_2^2 - \|f_i^a - f_i^n\|_2^2 + \alpha \right]_+$$



Name-entity Recognition

- In **EHRs** physicians register **relevant information** about patients: symptoms, the diagnosis, family history, treatments, the evolution at the time. But can be **difficult to analyze** being **unstructured** data and **complex clinical language**.
- **NER** is the task of identifying and **categorizing key information** (**entities**) in text. An entity can be any word or series of words that consistently refers to the same thing.
- Fine-tuning **BioBIT** and **Focal loss** to handle **class imbalance** to use the concepts extracted as features for precision medicine system.



Paziente di 77 anni. Ex fumatore dea 40 anni. Pensionato. In suguito a

comparsa di tosse, vengono prescritti dal pneumologo curante
•PSY

accertamenti radiologici che evidenziano neoplasia ilare destra e
•EXA •CAN •POS

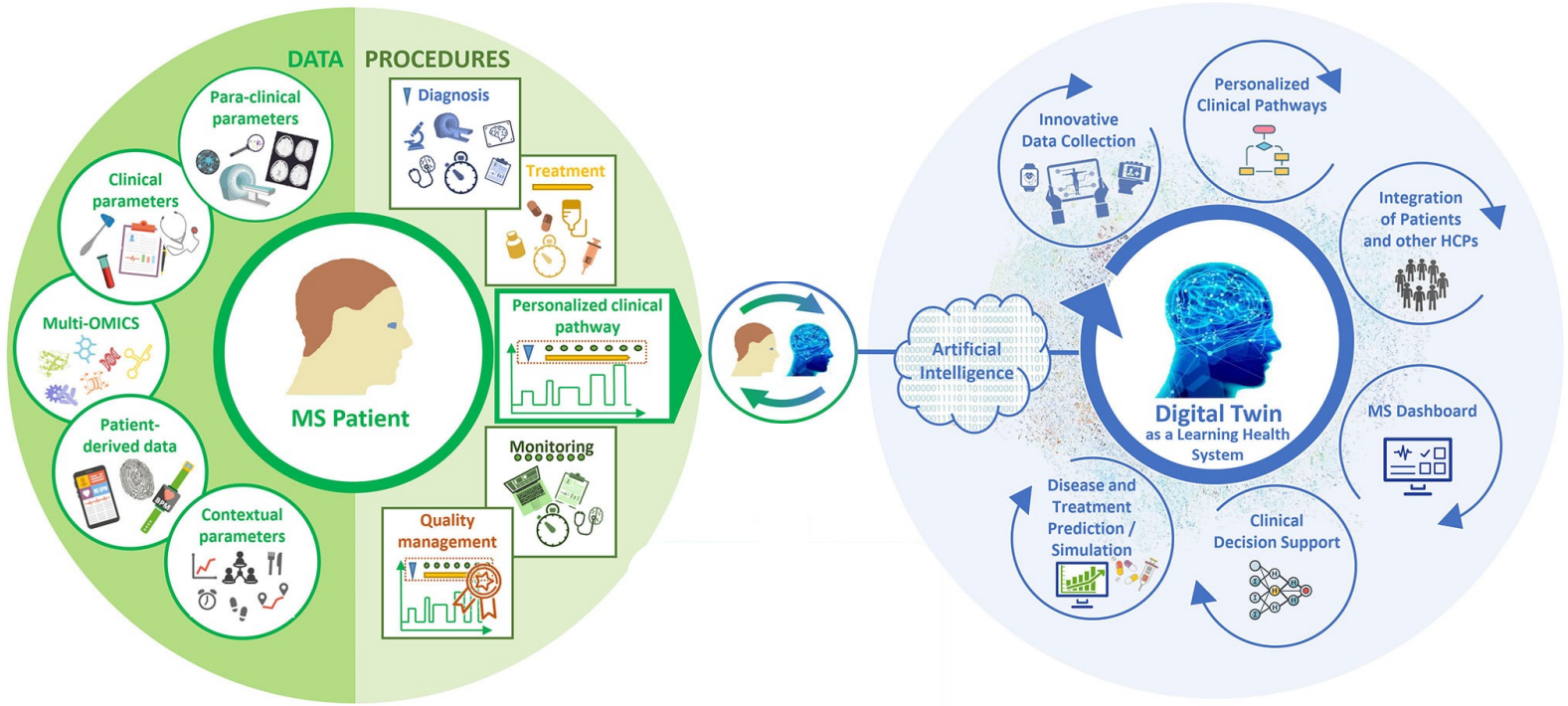
linfodadenopatia mediastinica. Vista il sospetto per patologia
•FAN •POS •FAN

neoplastica di origine polmonare, si prescrive:
•POS

Virtual Scanner

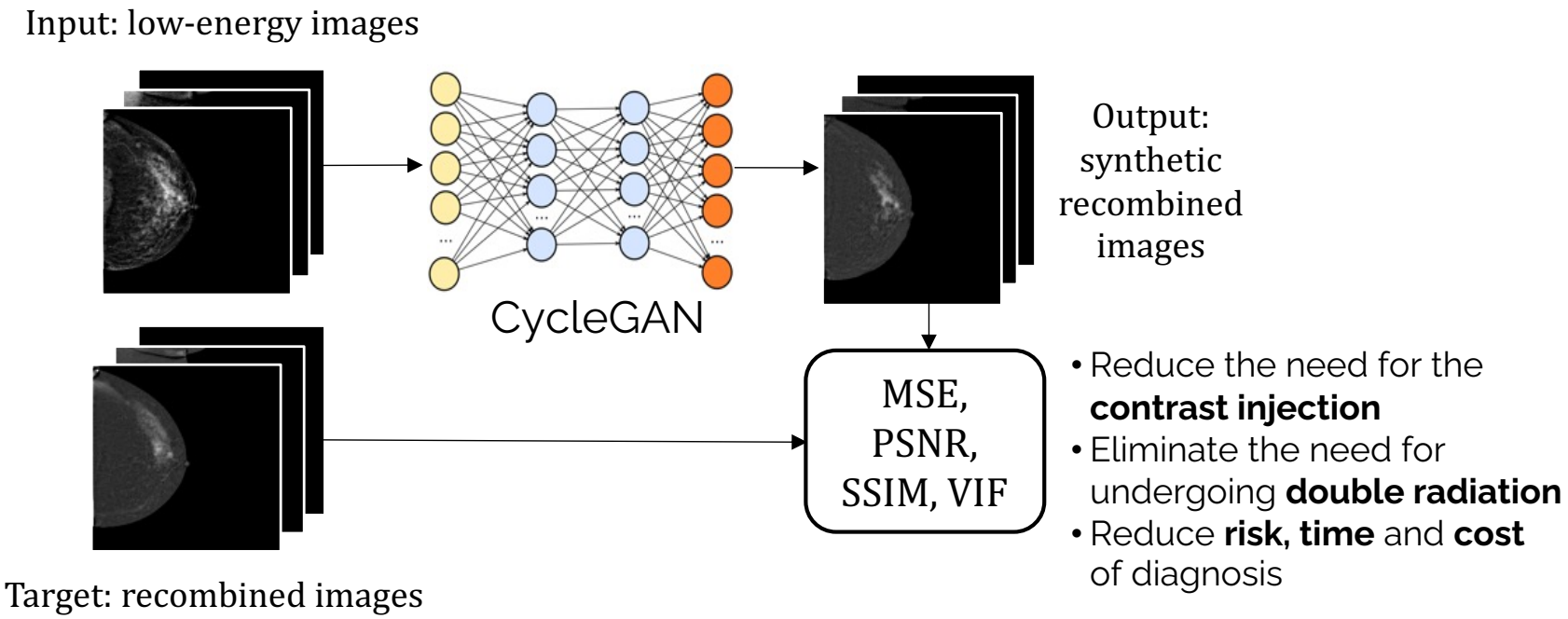
Virtual Scanner

- In a metaverse for intelligent healthcare, a virtual scanner refers to a **computer-generated imaging device** that uses virtual reality technology to **create medical images** of a patient's body.
- Without the need for **invasive procedures**, also **minimizing patient discomfort** as well as allowing medical professionals to **view and manipulate images** in ways that would not be possible with **traditional imaging techniques**.



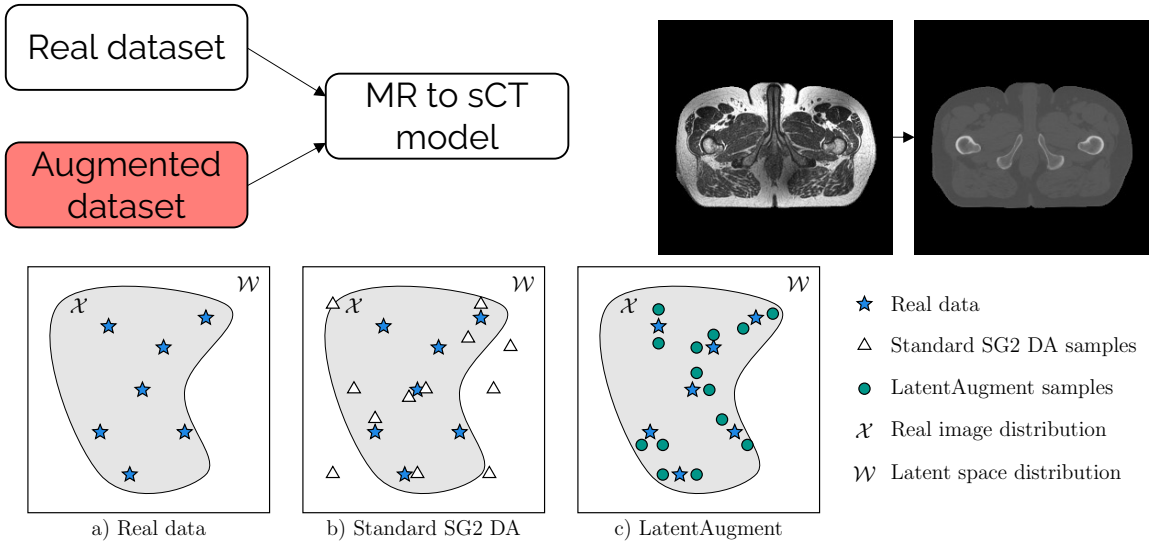
Virtual Contrast Enhancement

- **CESM** is a dual-energy technique for breast imaging. The injection of an iodinated **contrast medium** enhances **lesion visibility**. This results in **higher diagnostic accuracy** compared to standard mammography.
- **Issue**: The use of the contrast medium can have **side effects**, and CESM involves a **higher radiation dose** than standard mammography.
- **Solution**: **Generative models** performing **Virtual Contrast Enhancement** on CESM images.



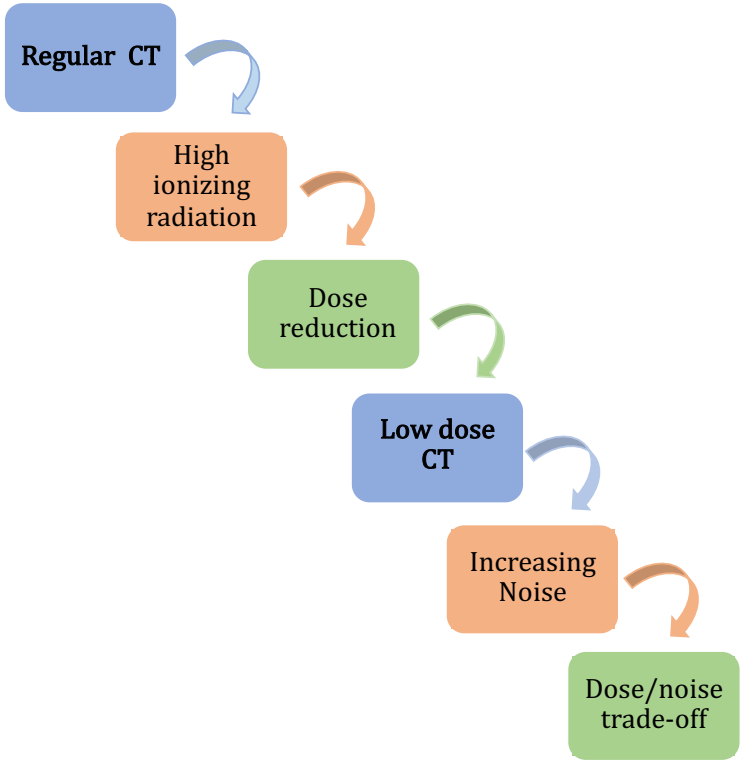
MR to sCT translation

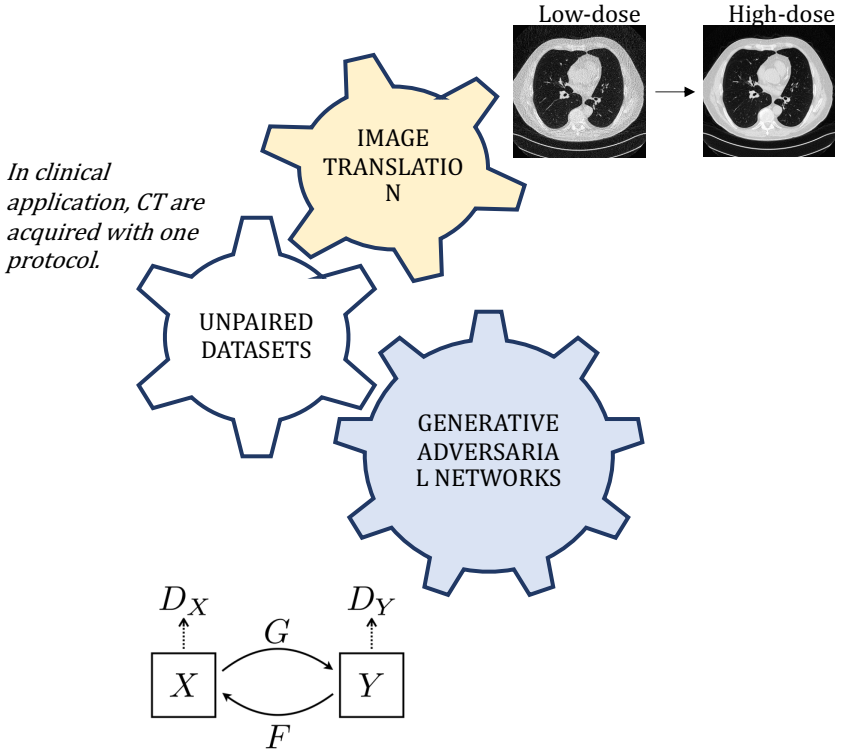
- Taking **multiple images** can be **cost-prohibitive**, **burdensome to the patient**, and problematic in light of **CT ionization risk**. For these reasons, **MR-only treatment planning** has become an attractive alternative -> **MR-to-CT image translation.**
- **GANs** are commonly used to **synthesize new images** but current methods do not allow **control over the generation process**, and especially not for **data augmentation**.
- We provide a guide to the generation process considering the **trade-off between fidelity and diversity in the generated images**. Generating points "**close but not too close**" to the training data.



Low-dose CT Denoising

- It has become common practice to use **LD acquisition protocols** which **minimize the radiation exposure** for the patient, **decreasing of the overall SNR**, compromising the **diagnostic quality** of the CT scans.
- From the hypothesis that the noise due to **LD protocols has a textural nature**, thus a **texture-based loss** will be beneficial during training allowing a **better denoising quality and faster training**.





Thanks for your time

For any doubts and suggestions, contact:
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or

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