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From Few to None: Exploring Few-Shot, One-Shot, and Zero-Shot Deep Learning in Clinical Settings

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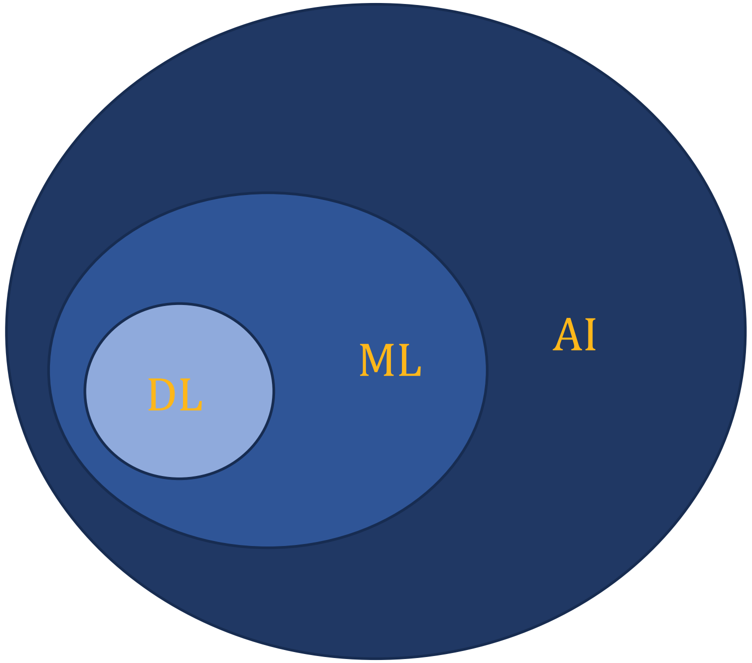
Outline

- Introduction to Deep Learning
- Deep Learning Applications in Medical Imaging
- Challenges in Medical Imaging
- Few-shot learning
  - Image Augmentation
  - Meta-Learning
  - Transfer-Learning
  - Example

What is Deep Learning?

- Subset of Machine Learning
  - Neural Networks
- Automatically learns hierarchical features
- Captures intricate patterns and abstractions
- Complex and Large dataset
  - Unstructured data as well as structured data
  - Example: images and text
- Help clinical experts in the interpretation as well as diagnosis



What is Deep Learning?

- Neural Networks
  - Inspired by the structure of the human brain.
- Multiple layers of inter-connected nodes
- More recent architectures
  - Convolutional Neural Networks (CNN)
  - Recurrent Neural Network
  - Transformers

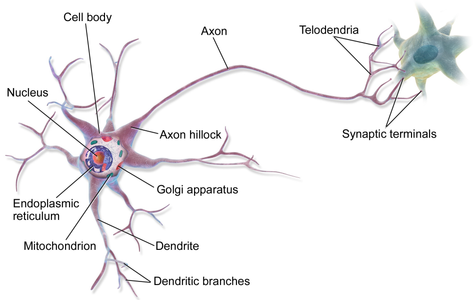
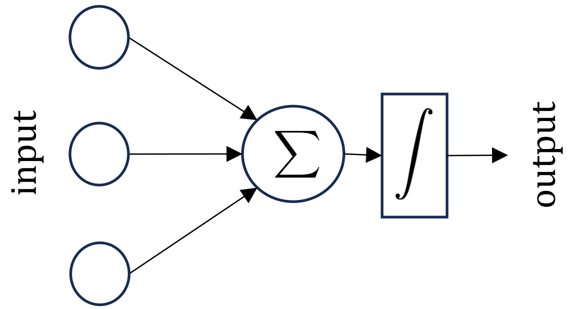
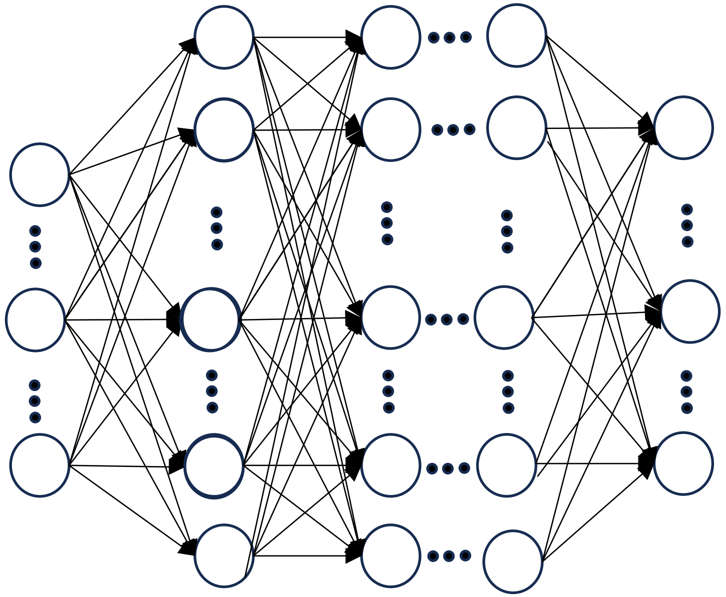


Image form https://en.wikipedia.org/wiki/Neuron



Perceptron



DNN

Applications of Deep Learning in Medical Imaging

- Classification
- Detection
- Segmentation
  - Semantic
  - Instance
- Registration

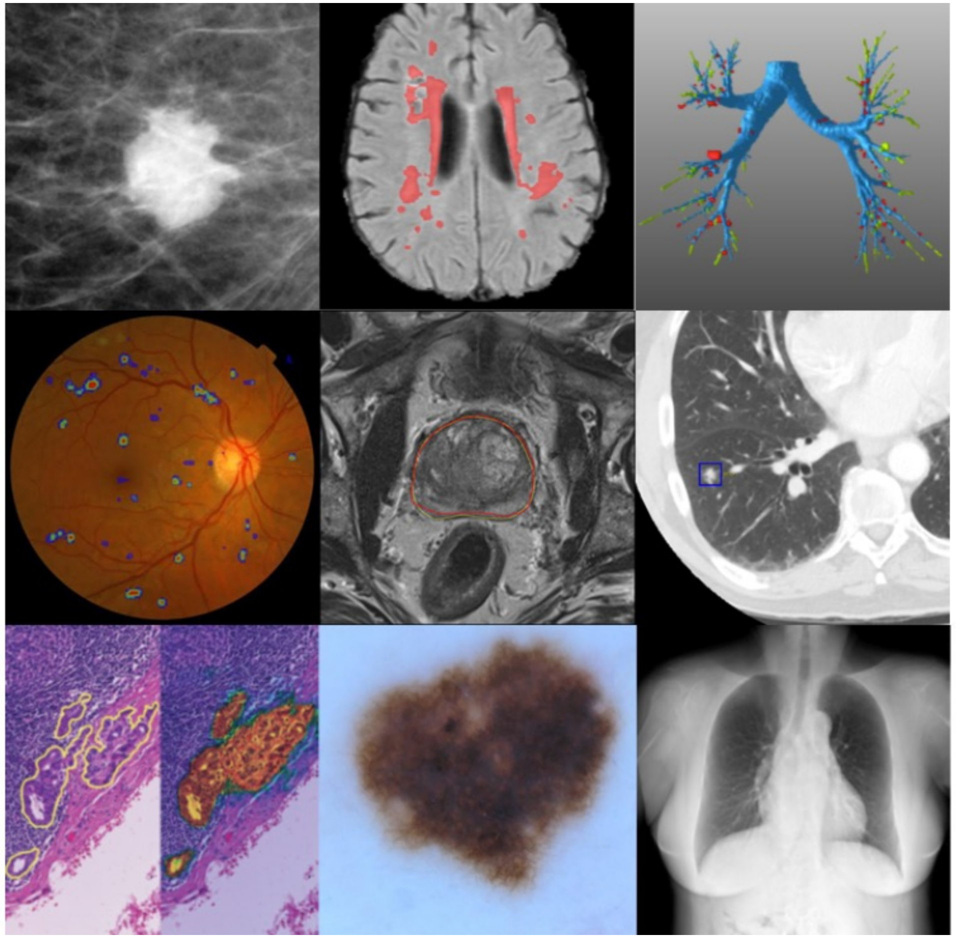


Image from [5]

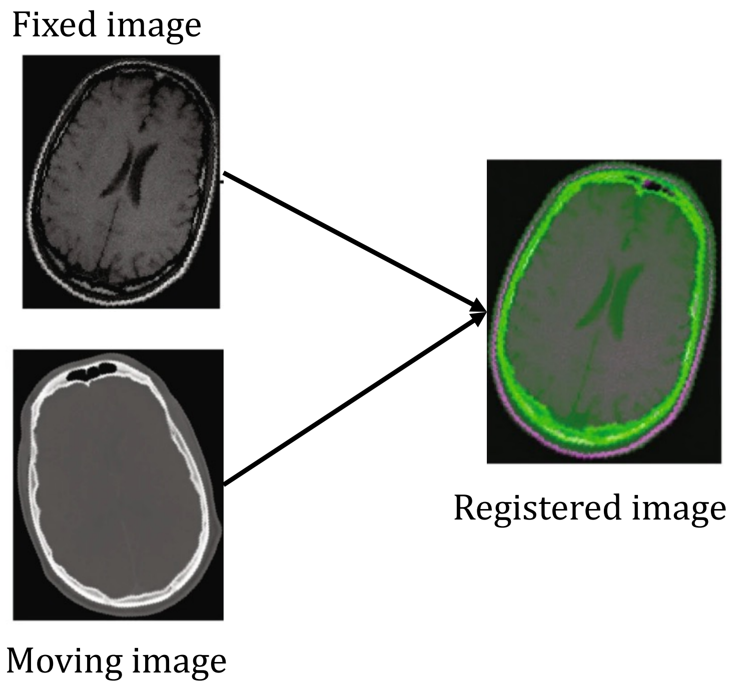
Classification & Registration

Classification

- Image/exam classification
  - E.g., Disease present or not?
- Object or lesion detection

Registration

- Spatial alignment of medical images
  - Images form different modalities (e.g., MR and CT scan)
  - Images taken from same subject in different times



Multi-modal image registration from [8]

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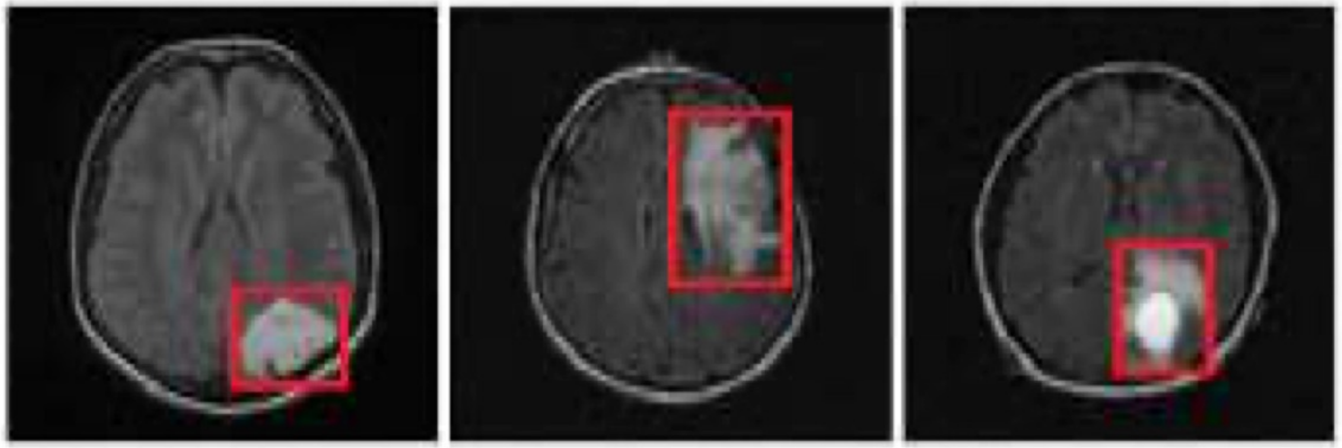
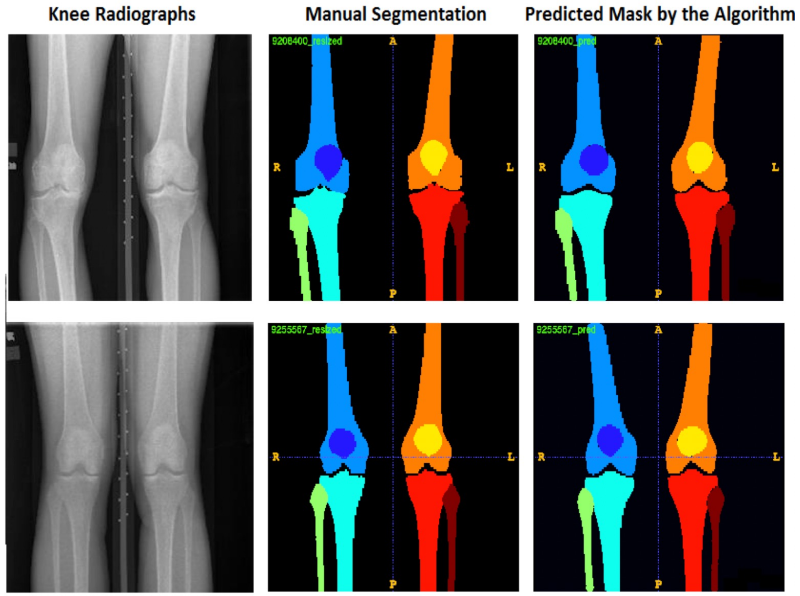
Detection



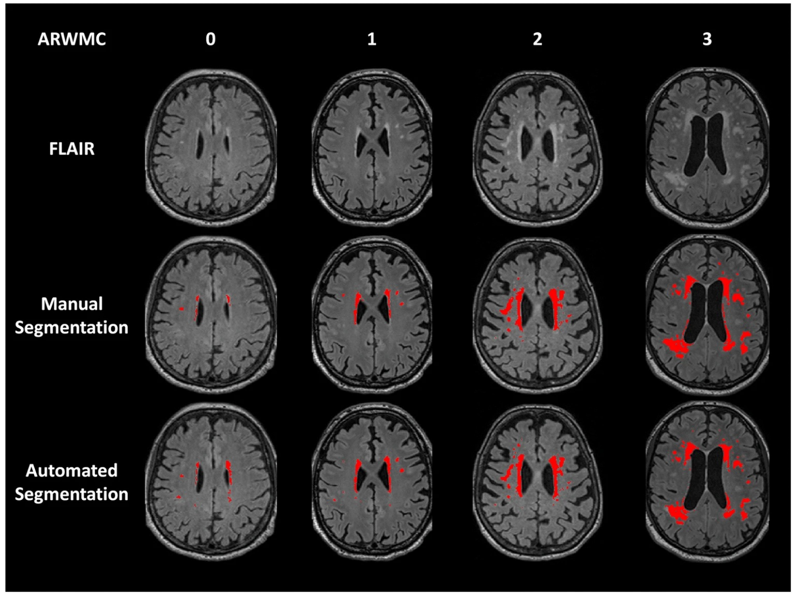
Brain tumor detection: from [3]

Semantic Segmentation

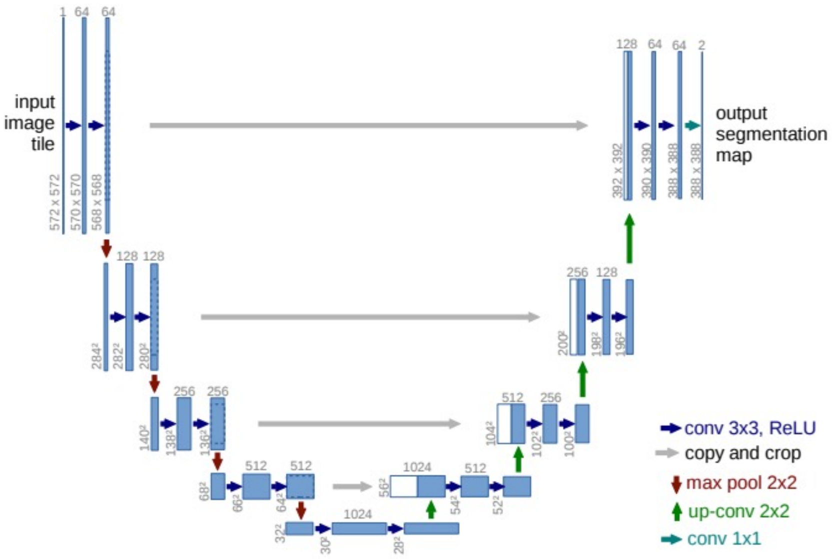
- Categorizing each pixel in an image with specific labels



Knee Radiograph segmentation: Image from [1]



White matter hyperintensity segmentation from [6]



U-Net network from [7]

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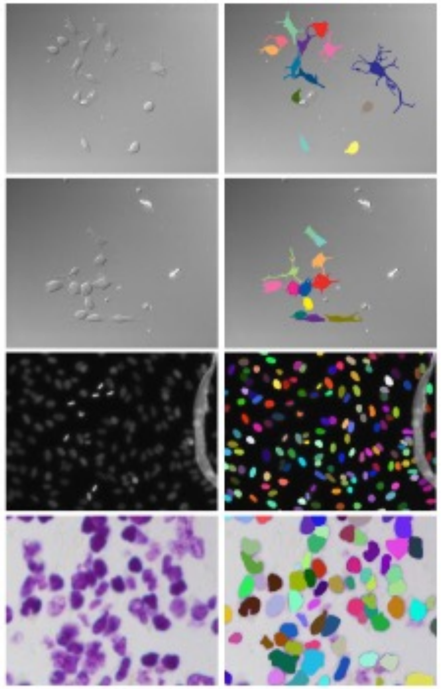
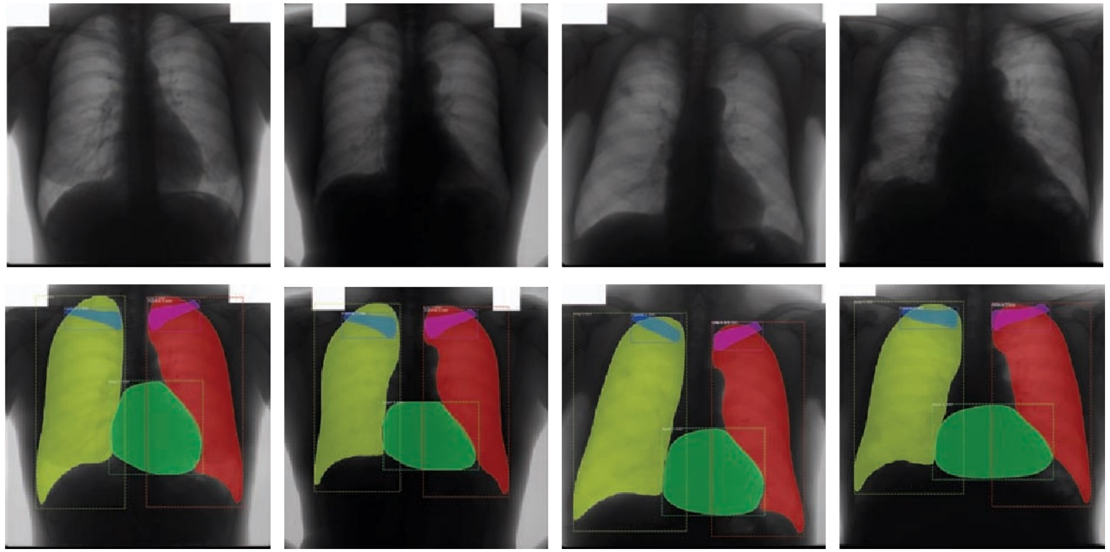
Instance Segmentation

- Identifying and delineating individual objects or instances within medical images



Cell Instance segmentation from [2]



Segmentation of anatomical structures in chest radiographs [9]

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Challenges

Class Imbalance

Ex. Sarcoma Classification

Explainability

Data Scarcity

Irregular shapes

Data Scarcity Solutions

- Labeled (Data) Efficient Approaches
  - Unsupervised Learning
    - No labeled data is required in training
    - Large amount of unlabeled data is required
  - Semi-Supervised Learning
    - Some labeled is required
  - Transfer Learning
    - Adapting the model to our downstream task (e.g., brain lesion segmentation)

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Data Scarcity Solutions

- Labeled (Data) Efficient Approaches
  - Transfer Learning
    - **Few-shot Learning methods ☺**
      - Adapt the model to a new task using very limited labeled data
- Obtaining more data
  - Combining data from different data centers (e.g., hospitals)
- Distribution shift challenge
  - Training data and testing data do not follow a similar distribution
    - Domain Adaptation, Domain Generalization

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Few-shot learning

- Training models to make accurate predictions or classifications when provided with very limited amounts of labeled data.
- The models train on a dataset with few examples per class
- Types of few-shot learning:
  - One-shot
    - In this scenario, there is only one example per class
  - Few-shot (N-shot learning)
- Common strategies:
  - Transfer learning
  - Meta-learning
  - Data Augmentation
- Difference from Zero-shot learning:
  - In zero-shot, there is no training on the dataset
  - Inference phase on unseen datasets

Image Augmentation

- Objective
  - Increase dataset variability, combat overfitting, and improve generalization from limited data.

- Why?
  - Combat Overfitting
  - Enhance Generalization
  - Improve performance
  - Mimic real-world scenario

- Techniques:
  - Rotation
  - Cropping
  - Flipping
  - Brightness and contrast adjustment

Meta Learning

- Definition
  - Meta-learning, or "learning to learn", involves training models on the task of learning itself. It adapts rapidly to new tasks with minimal data.
- Objective
  - To generalize from a set of tasks so that the model can quickly adapt to new, unseen tasks.
- Methods
  - Model-Agnostic Meta-Learning (MAML):
    - It learns an initialization
  - Memory Augmented Neural Networks (MANN)
    - It uses an external memory matrix to store information.
  - Meta Network
    - the meta-network generates the weights for the primary network based on the specific task information.
- Advantages
  - Rapid Adaptation
  - Resource Efficiency
- Applications:
  - Few-shot learning
  - Transfer learning
  - Reinforcement learning

Transfer learning

- Definition
  - Transfer learning is a machine learning technique where a model developed for one task is reused as the starting point for a model on a second task.

- Advantages
  - Faster Training
  - Require less data
  - Improved performance

- Methods
  - Feature Extraction
  - Fine-tuning

Few-shot example in Medical imaging

- Data augmentation using learned transformations for one-shot medical image segmentation [4]

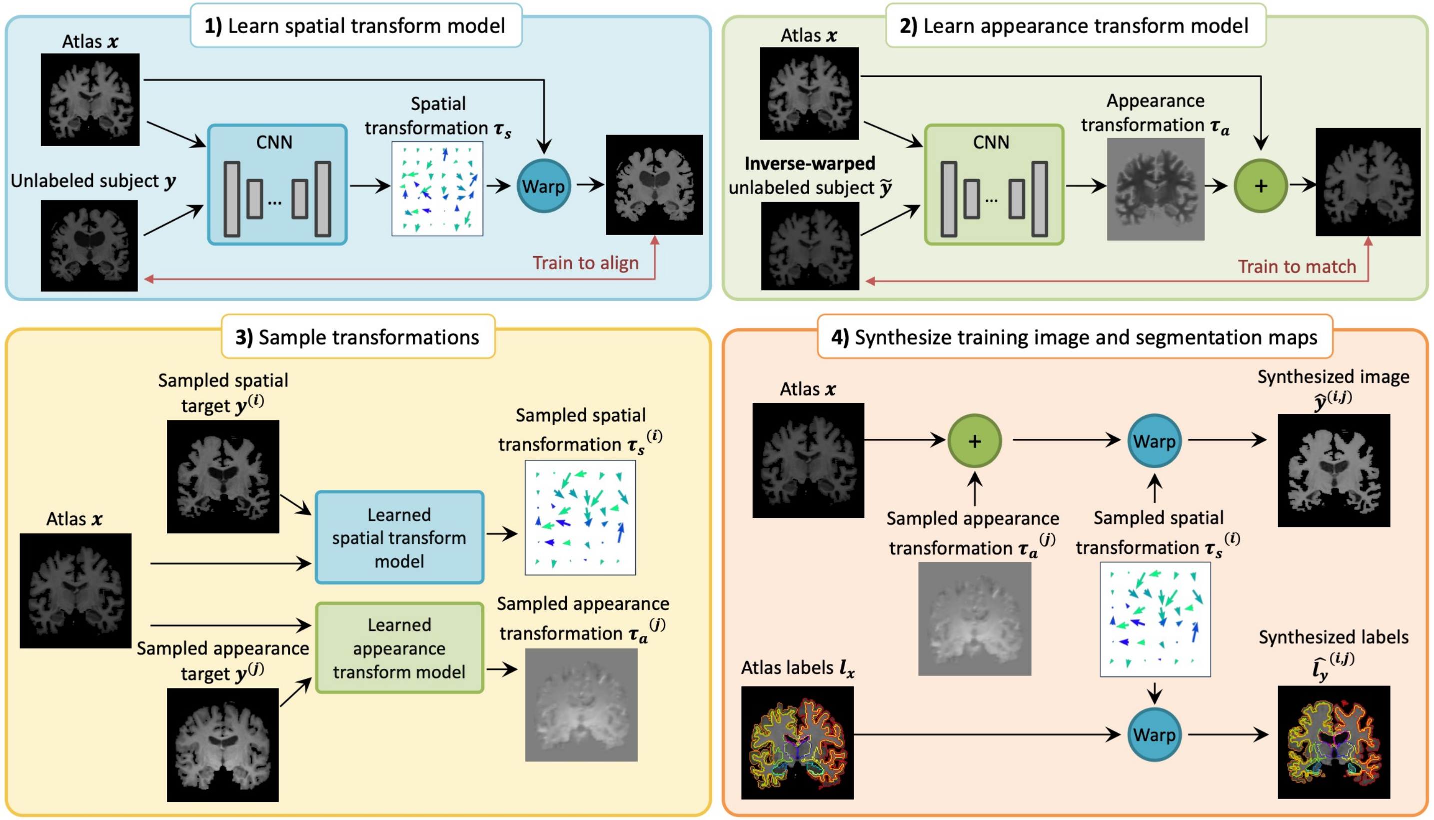

Image from [4]

Conclusion

- Adopting the existing CV method for medical imaging is non-trivial
  - Imbalance data, lack of adequate data, explainability, and lack of canonical orientation
- Few-shot learning can be a promising approach for adapting pre-trained DL methods
- Few-shot learning common techniques:
  - Transfer learning
  - Meta-learning
  - Data Augmentation
- Types:
  - One-shot
  - N-shot

Thank you

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