18th International Symposium on Visual Computing

Lake Tahoe, NV

October 16-18, 2023

Explainable Deep Few-shot Learning on the Cloud and its Application in Medical Imaging Informatics

Presenters and Organizers:
Dr. Ahmad P. Tafti
Nickolas Littlefield
Aysan Aghazadeh
Ismaeel Siddiqui
Soheyla Amirian
Arvind Rao
Iman Zadeh
Bryan Barker
Johannes Plate
Shandong Wu

Health + Explainable AI

Hexai

MIIE Lab

Applied Machine Intelligence Initiative and Education

ORACLE for Research

University of Pittsburgh

Outline of Tutorial

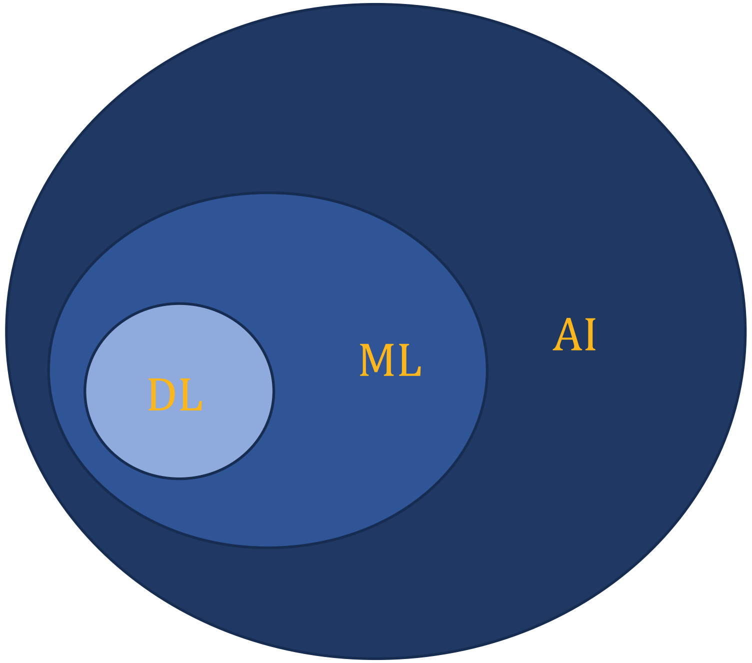
- Introduction (2:40 – 3:10 PM)
- Oracle Cloud Presentation (3:10 – 4:00 PM)
- Break (4:00 – 4:30 PM)
- Explainability Presentation (4:30 – 5:30 PM)
- Hands on Practice in Python (5:30 – 6:45 PM)

Outline of Introduction Presentation

- 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

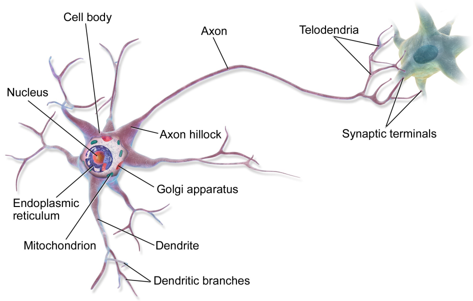
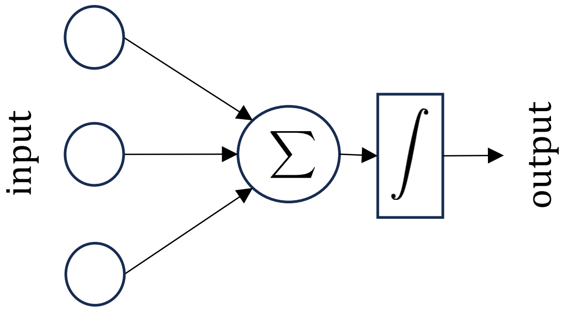
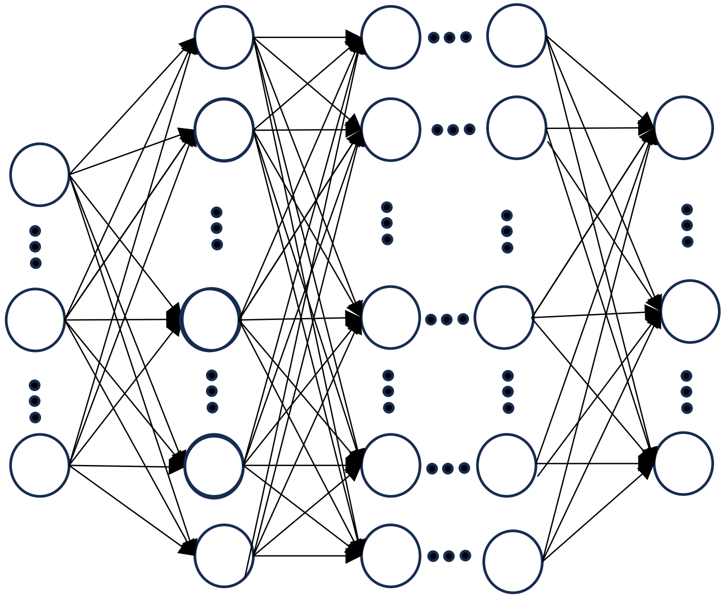


Image form https://en.wikipedia.org/wiki/Neuron



Perceptron



DNN

Applications of Deep Learning in Medical Imaging

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

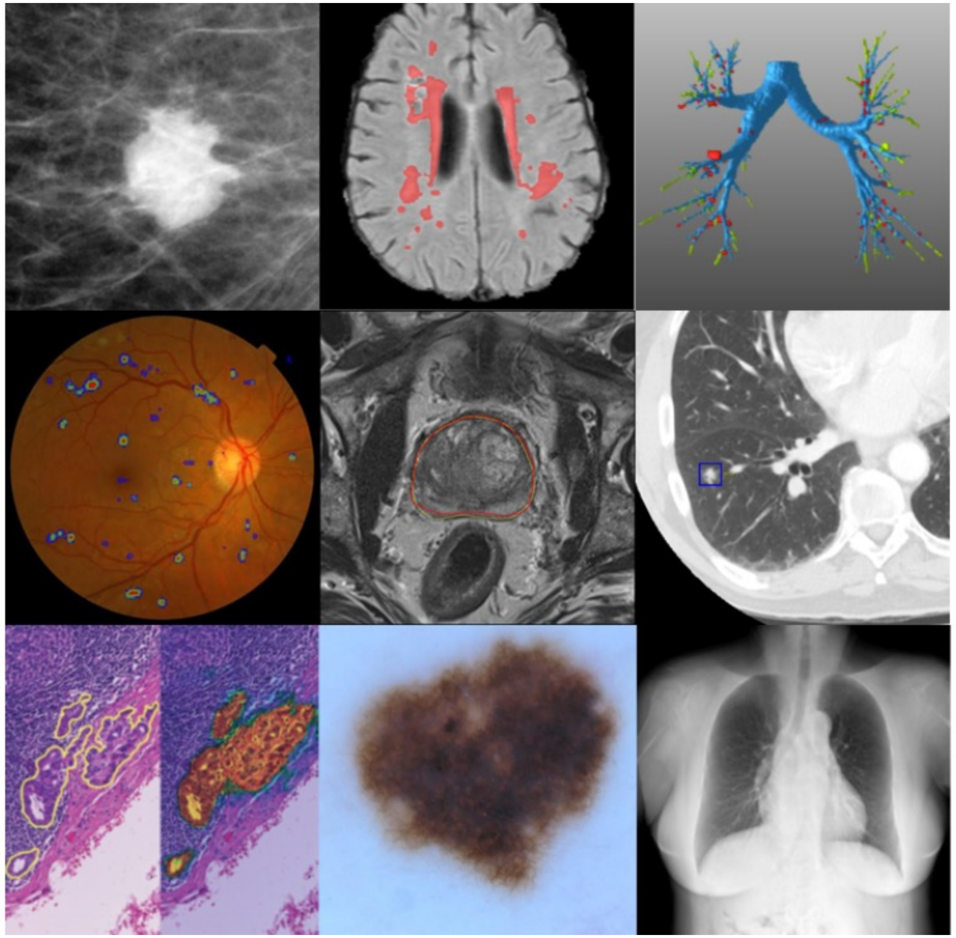


Image from [5]

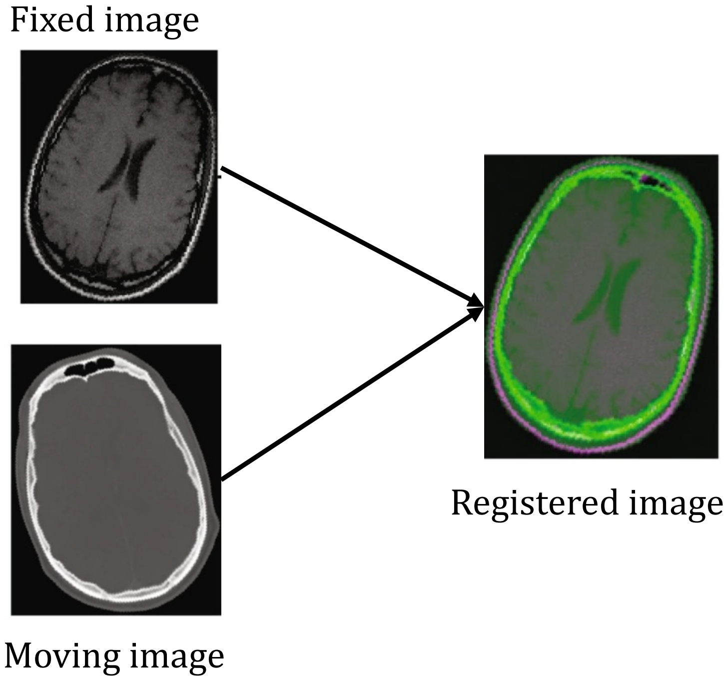
Classification & Registration

Classification

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

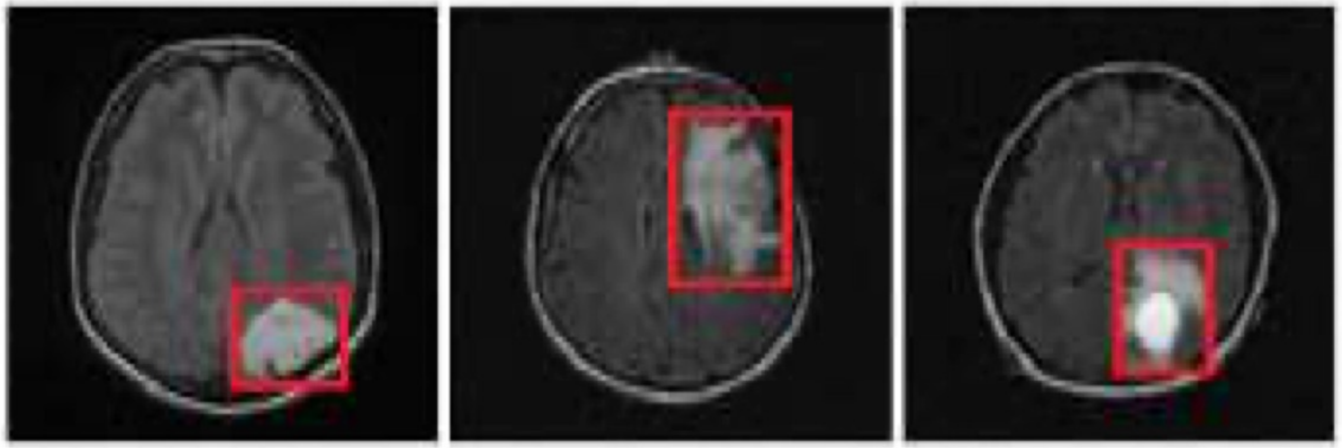
Registration

- 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]

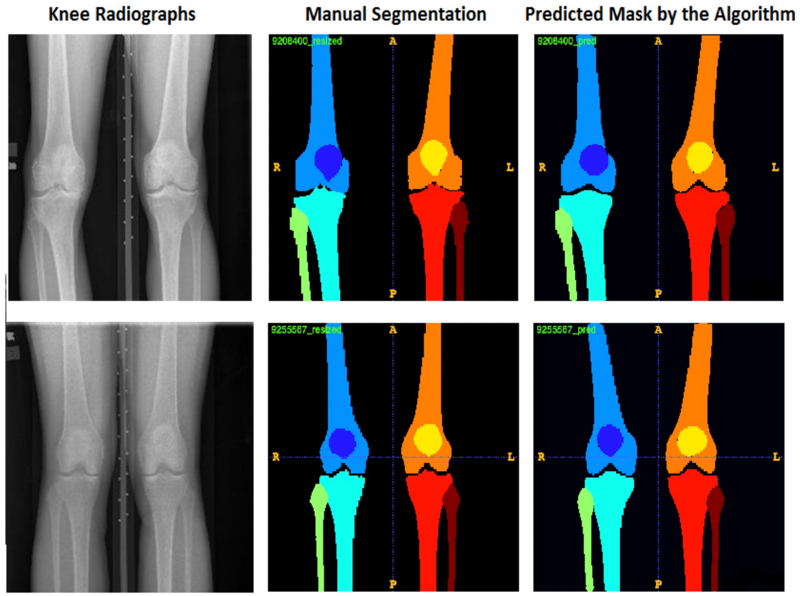
Detection



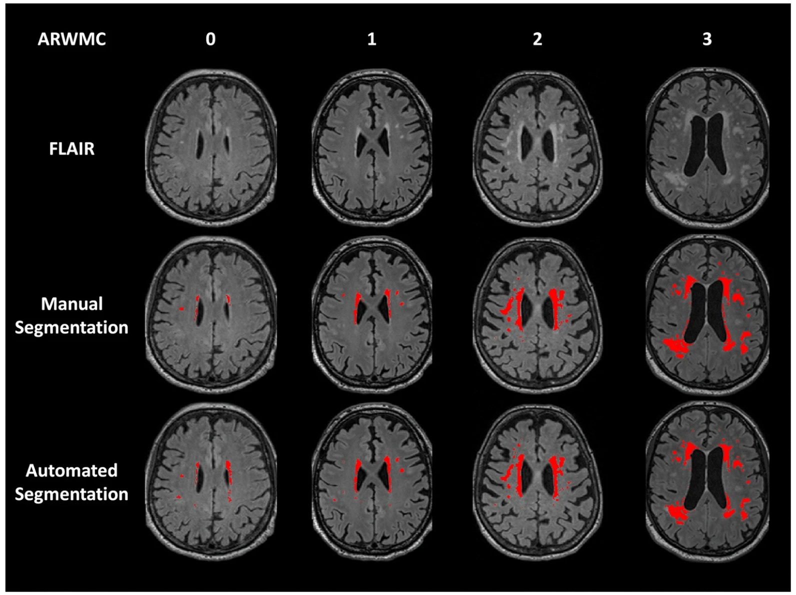
Brain tumor detection: from [3]

Semantic Segmentation

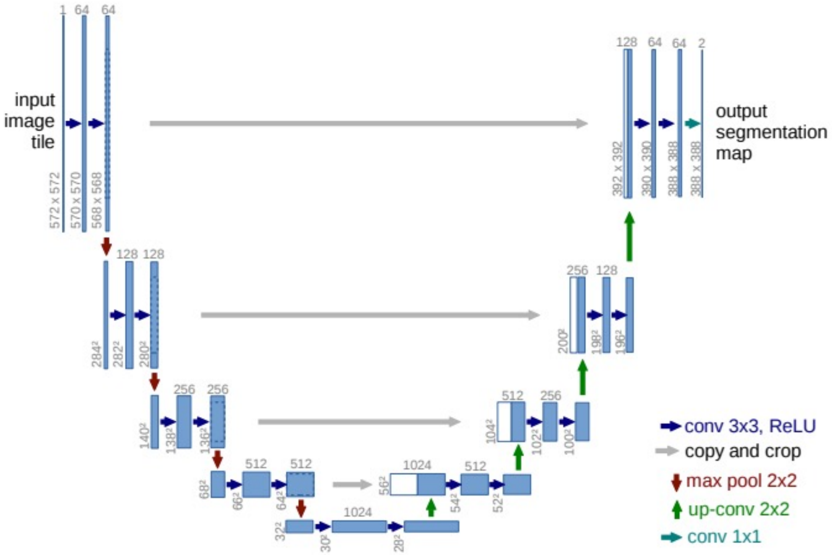
- Categorizing each pixel in an image with specific labels



Knee Radiograph segmentation: Image from [1]



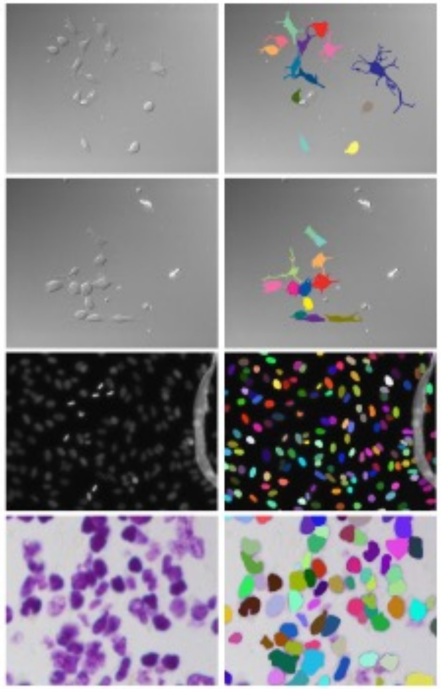
White matter hyperintensity segmentation from [6]



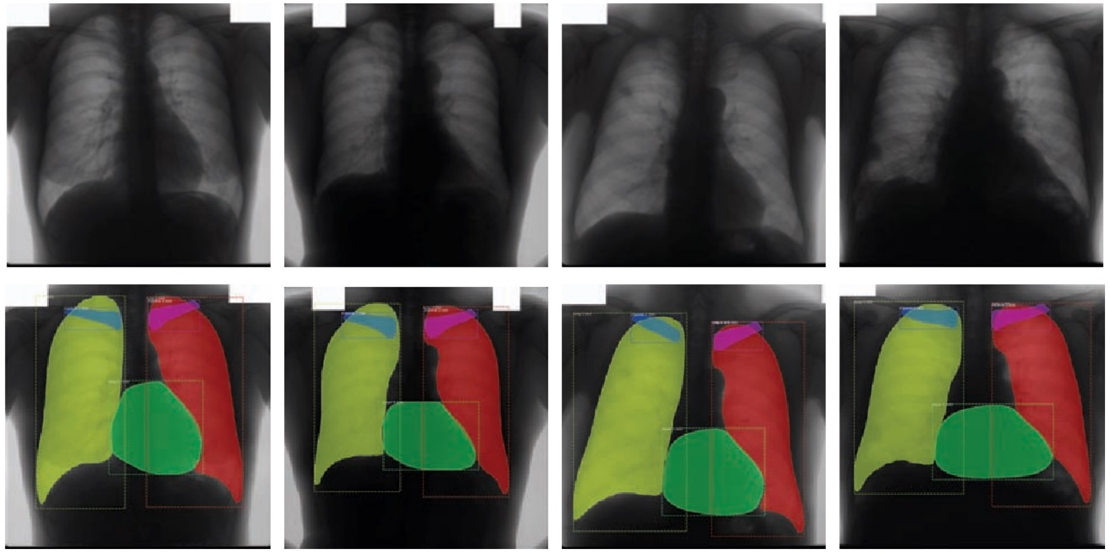
U-Net network from [7]

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]

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)

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

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

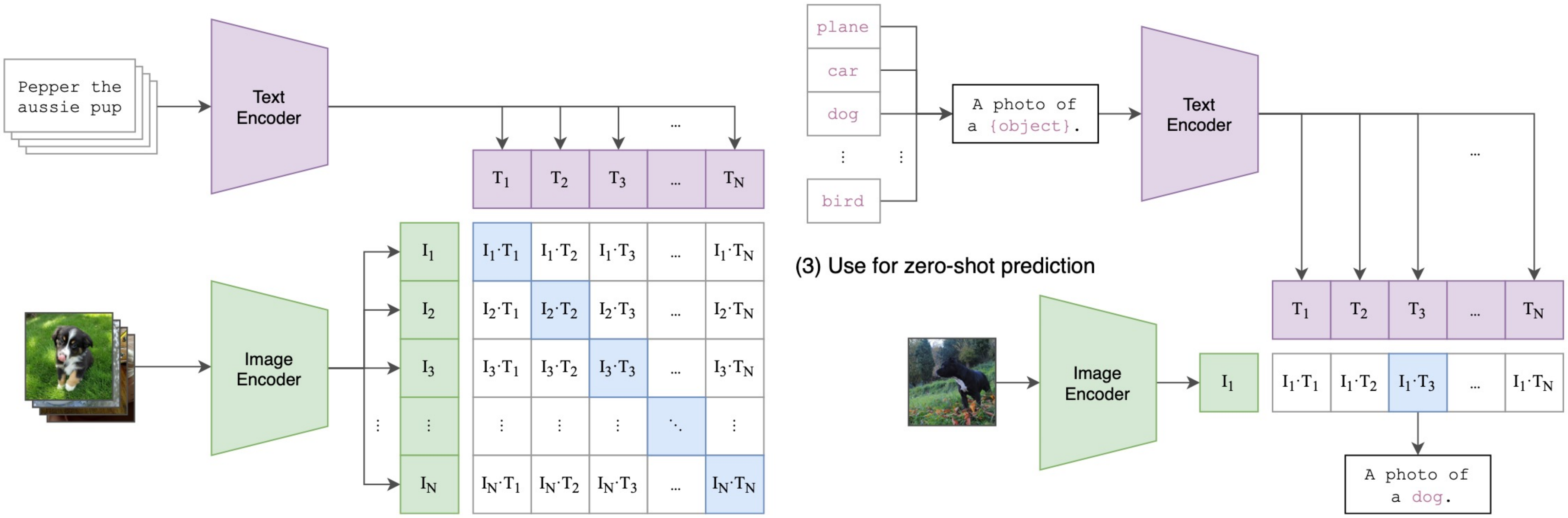
Transfer learning

- 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 and Zero-shot examples in general CV



CLIP: Image from [6]

Contrastive representation loss

$$L = \frac{1}{2N}\sum_{i=1}^{N}[y.\,d_i^2 + (1\ - y).\max(\alpha - d_i, 0)^2]$$

- L is the contrastive loss.
- N is the total number of pairs.
- d_i is the Euclidean distance between the two embeddings (or representations) in the pair ii.
- y is a binary label indicating whether the pair is similar (1) or dissimilar (0).
- α is a margin that defines how far apart the dissimilar items should be. It's a hyperparameter.

Health +
Explainable AI
Hexai

Few-shot and Zero-shot examples in general CV

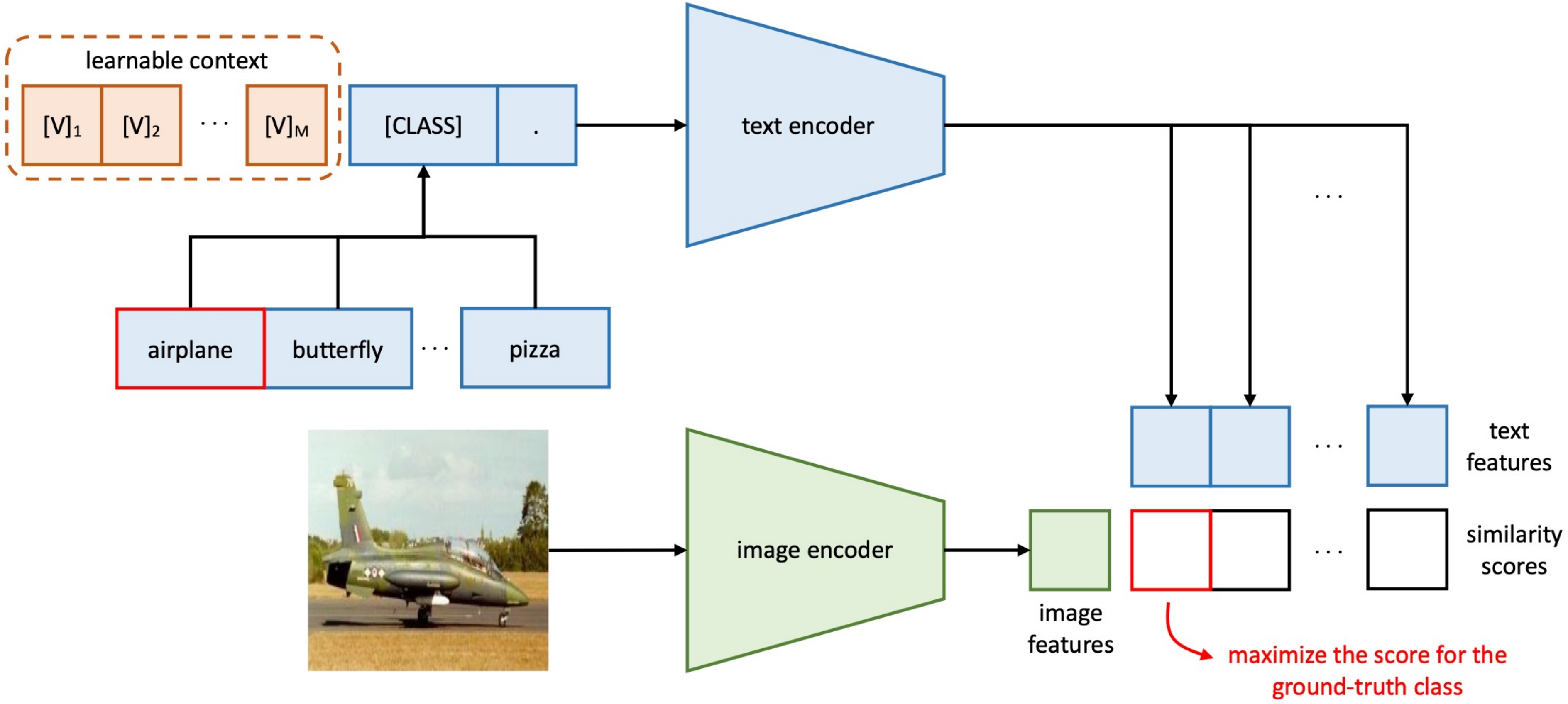


Image from [7]

Few-shot example in Medical imaging

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

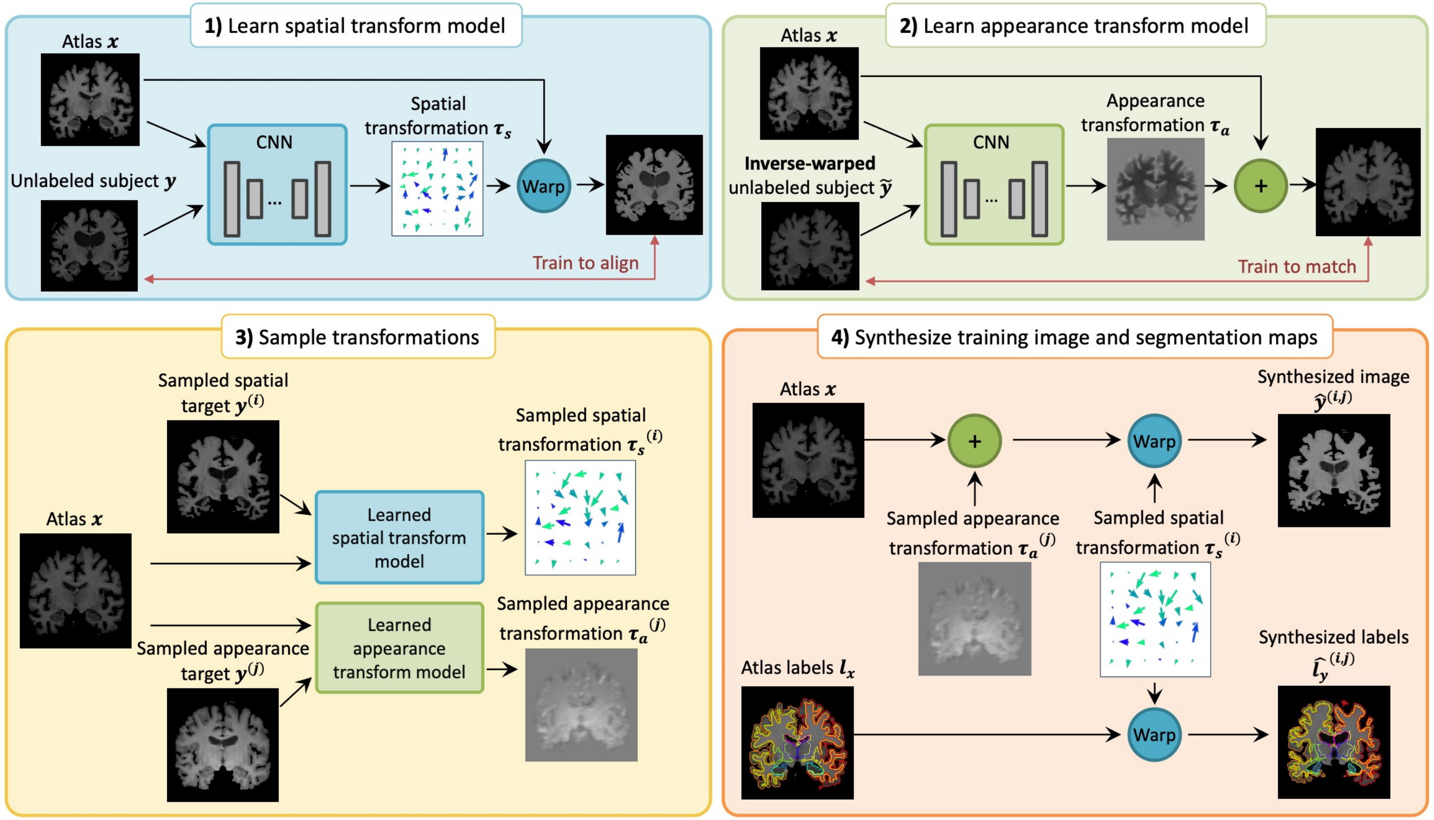


Image from [4]

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

References

1. Littlefield, Nickolas (2023). "Learning Unbiased Image Segmentation: A Case Study with Plain Knee Radiographs".

2. Yi, Jingru, et al. "Multi-scale cell instance segmentation with keypoint graph based bounding boxes." Medical Image Computing and Computer Assisted Intervention–MICCAI 2019: 22nd International Conference, Shenzhen, China, October 13–17, 2019, Proceedings, Part I 22. Springer International Publishing, 2019.

3. S. Gull, S. Akbar and I. A. Shoukat, "A Deep Transfer Learning Approach for Automated Detection of Brain Tumor Through Magnetic Resonance Imaging," 2021 International Conference on Innovative Computing (ICIC), Lahore, Pakistan, 2021, pp. 1-6, doi: 10.1109/ICIC53490.2021.9692967.

4. Zhao, Amy, et al. "Data augmentation using learned transformations for one-shot medical image segmentation." Proceedings of the IEEE/CVF conference on computer vision and pattern recognition. 2019.Kim, Soopil, et al. "Bidirectional rnn-based few shot learning for 3d medical image segmentation." Proceedings of the AAAI conference on artificial intelligence. Vol. 35. No. 3. 2021.

5. Litjens, Geert, et al. "A survey on deep learning in medical image analysis." Medical image analysis 42 (2017): 60-88.

6. Radford, Alec, et al. "Learning transferable visual models from natural language supervision." *International conference on machine learning*. PMLR, 2021.Zhou, Kaiyang, et al. "Learning to prompt for vision-language models." International Journal of Computer Vision 130.9 (2022): 2337-2348.

7. Islam, K.T., Wijewickrema, S. & O’Leary, S. A deep learning based framework for the registration of three dimensional multi-modal medical images of the head.

8. Wang, Jie et al. “Instance Segmentation of Anatomical Structures in Chest Radiographs.” 2019 IEEE 32nd International Symposium on Computer-Based Medical Systems (CBMS) (2019): 441-446.