UNIVERSITY OF BIRMINGHAM

Cross-domain Image Analysis

Dr Qingjie Meng

School of Computer Science

University of Birmingham

Outline

- What is domain shift?
- Potential solutions
- Applications in medical image analysis

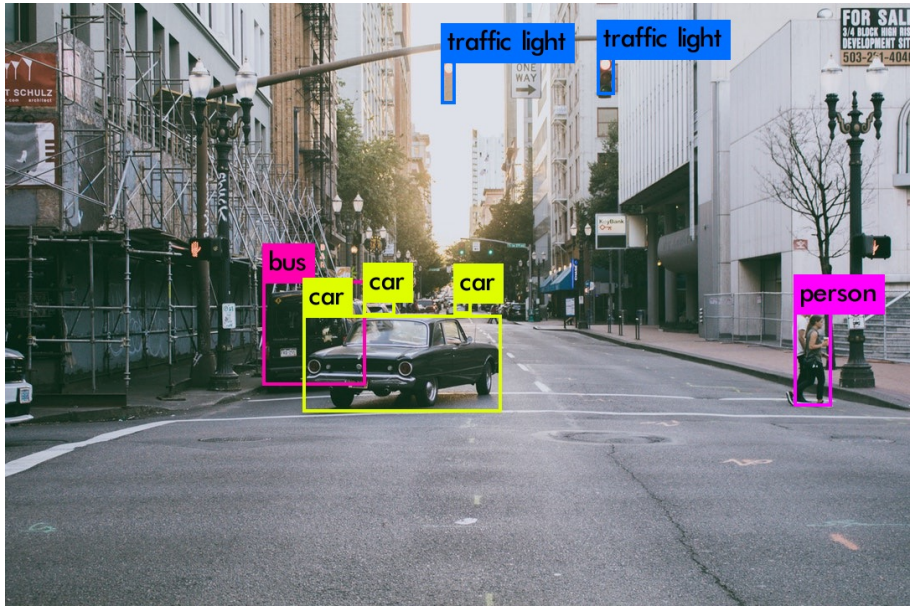
Image analysis tasks

Classification

Cat

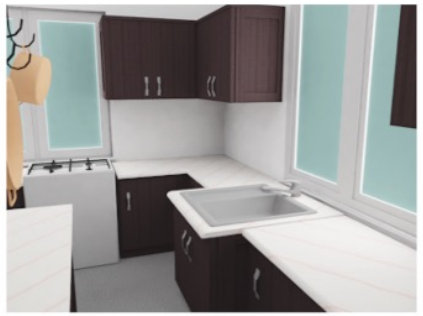
Dog

Detection

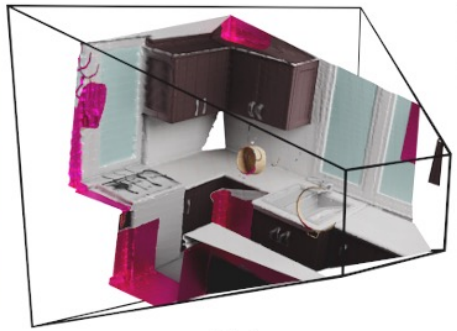


Generation

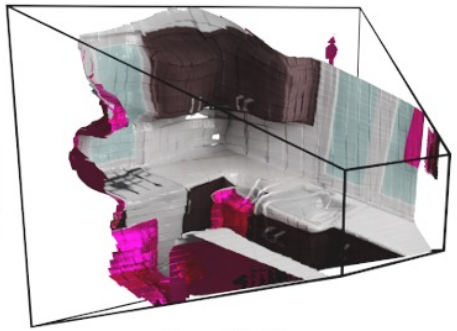
Image Segmentation



Input



GT



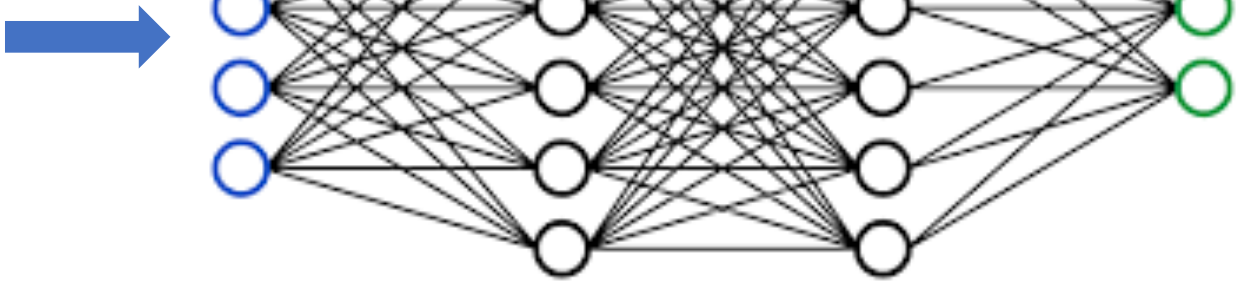
Prediction

3D Modeling

Neural networks – example 1

Classification task

Input image



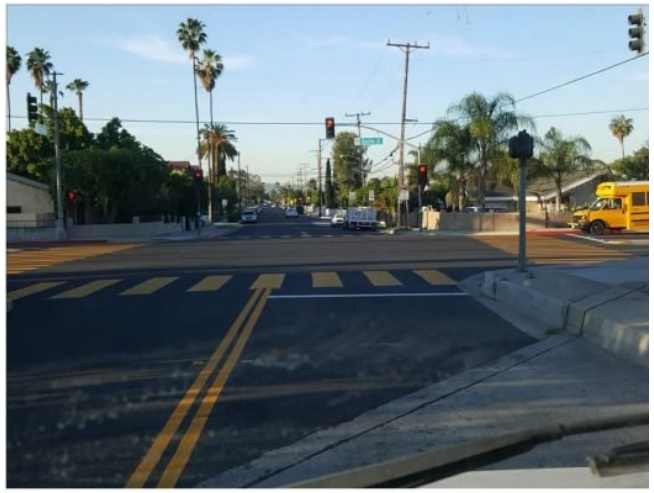
Output label

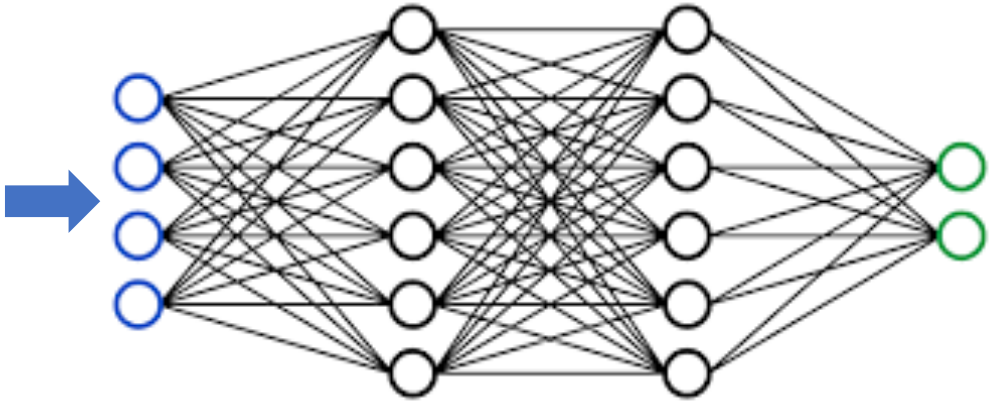
Cat

Neural networks – example 2

Segmentation task

Input image

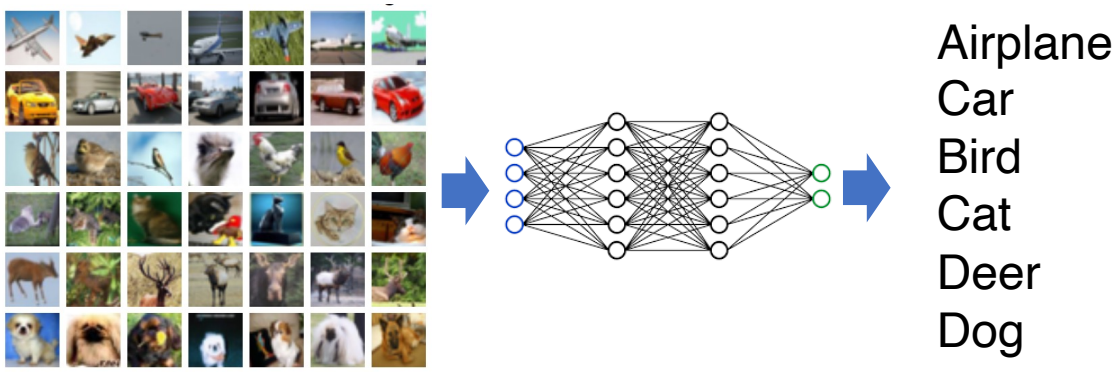




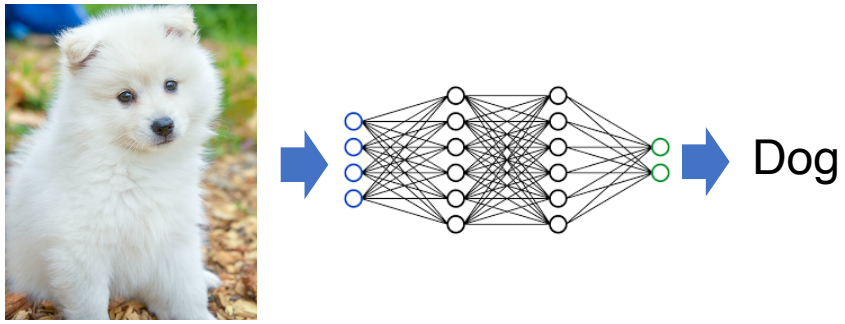
Output segmentation

How does neural network work?

Training



Testing / Inference



Neural networks – data

Assumption: the training and test data are drawn from the same distribution.

When we say that two datasets have the "same distribution," it means that the data points in both datasets follow a similar pattern in terms of their probability distribution. In other words, the shape, spread, and characteristics of the data in one dataset closely resemble those in the other dataset.

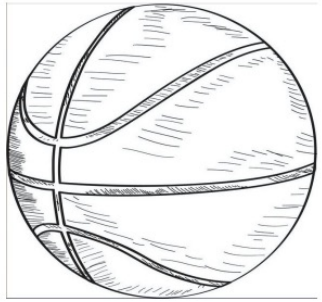
Example 1 Photo






Example 2 Sketch



Training data

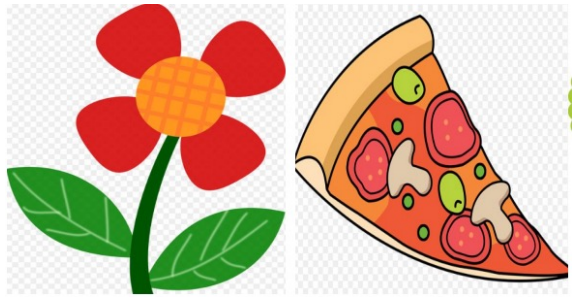
Test data

Domain shift

Domain shift: the different distributions of training and test data.

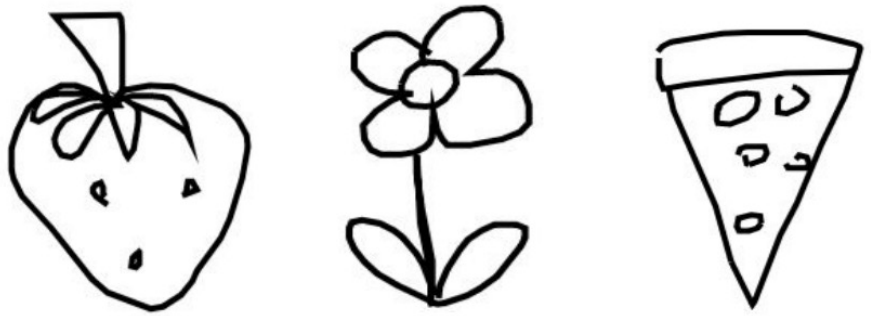
Train Painting

Test Clipart



Example 1

Train Quickdraw



Test Photo

Example 2

Challenge: domain shift issue result in low generalizability of neural networks.

Forms of domain shift

- **Covariate shift:** the changes in the distribution of the input variables.
  - Segmentation model trained on sunny streets and deployed on snowy streets.

- **Prior probability shift:** the changes in the distribution of the class variables.

When they take prior probability into account

  - Classification model trained on balanced data (cat : dog=1:1) and deployed on unbalanced data (cat : dog = 1:9).

- **Concept shift:** the changes of the relationship between the input variables and the class variables.
  - Making purchase recommendations based on web browsing behavior, trained on pre-pandemic data and deployed on data during pandemic.

How to address domain shift?

Application scenario: a neural network is trained on data from **source domain** (e.g., photos) and is going to be deployed on data from **target domain** (e.g., paintings).

- **Aiming at learning domain-invariant features during training:**

  Domain adaptation or transfer learning in a broader concept

- **Aiming at increasing data diversity during training:**

  Data augmentation

- **Aiming at adapting target domain data during test:**

  Test-time adaptation

Domain adaptation

Supervised, Semi-supervised and unsupervised domain adaptation

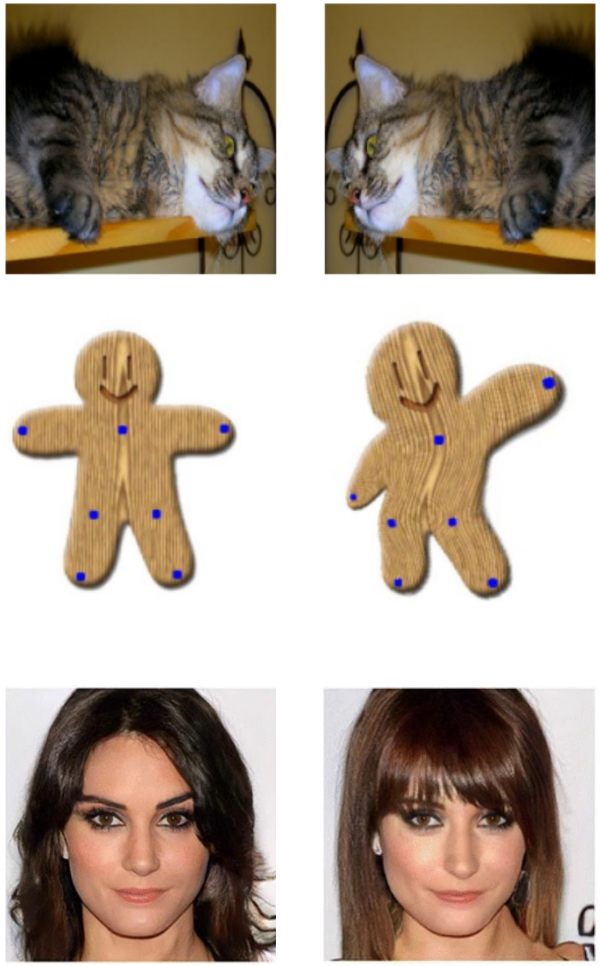
Method	Source domain		Target domain	
	Image	Label	Image	Label
Supervised	✓	✓	✓	✓
Semi-supervised	✓	✓	✓	limited✓
Unsupervised	✓	✓	✓	×

Domain adaptation scenarios

	Source domain	Target domain
One-to-One	S	T
Multi-Source	$S_1, S_2, \dots, S_N$	T
Multi-Target	S	$T_1, T_2, \dots, T_N$

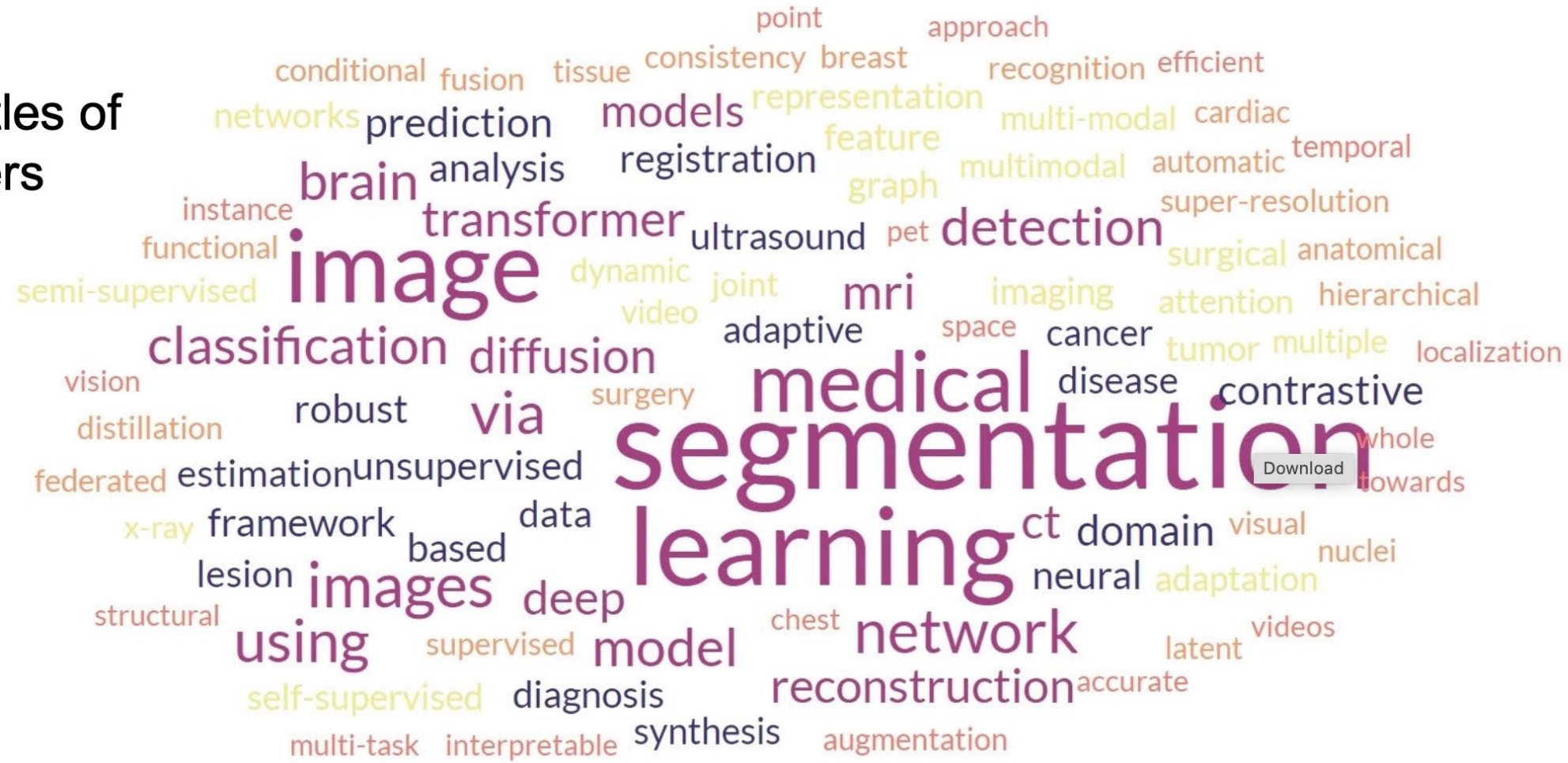
Data augmentation

- **Basic augmentation**:
  - Geometric transformations: scale, rotate, flip, shear, etc.
  - Cropping
  - Intensity operations: modifying contrast and brightness
  - Noise injection
  - …
- **Deformable augmentation**:
  - Deformable image registration
- **Advanced augmentation**:
  - Adversarial data augmentation
  - Generative adversarial networks (GAN) based augmentation
- **...**



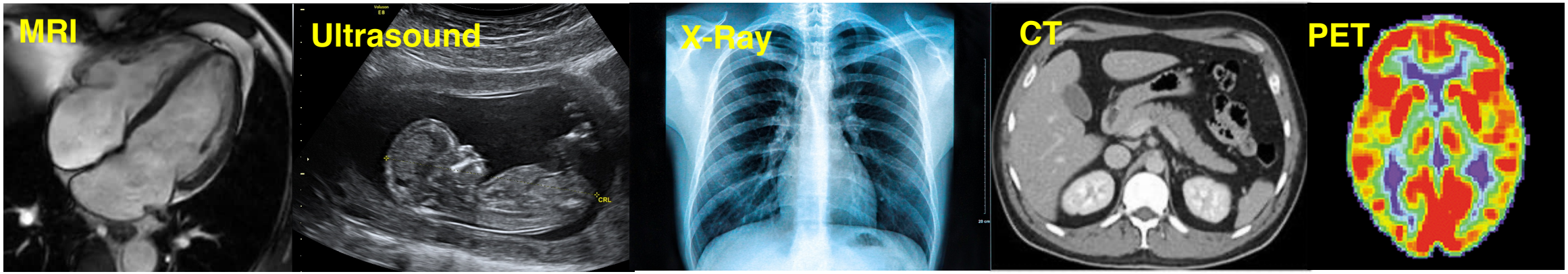
Medical image analysis

Words in Titles of all Posters



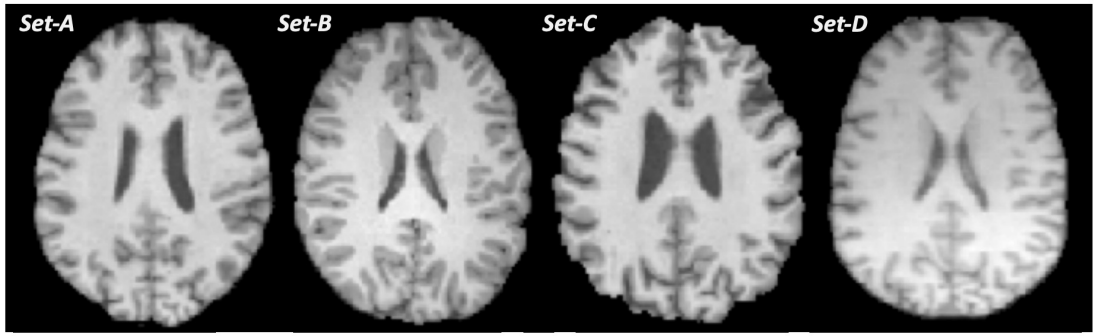
26th INTERNATIONAL CONFERENCE ON MEDICAL IMAGE COMPUTING AND COMPUTER ASSISTED INTERVENTION (MICCAI'2023)

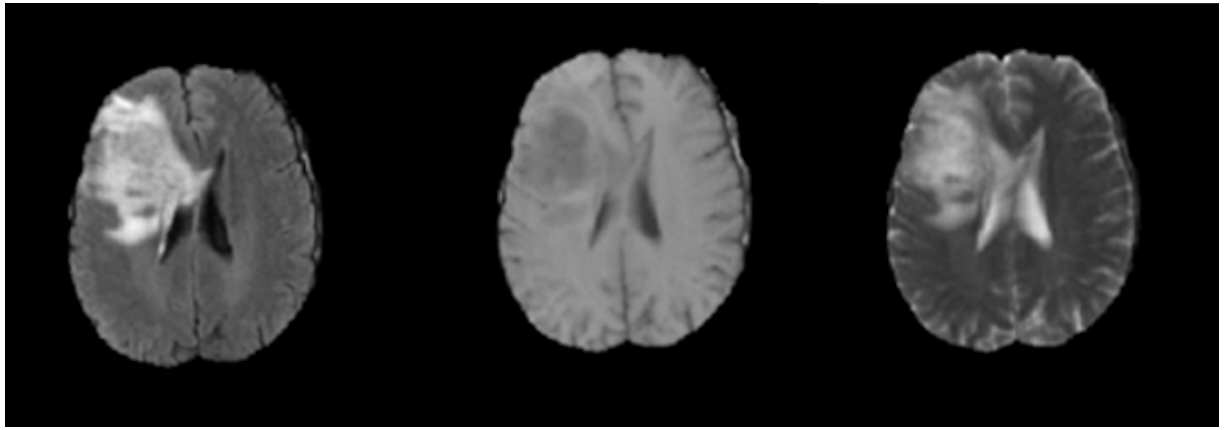
Domain shift in medical imaging



Different modalities

T1-weighted MRI





Flair MRI T1-weighted MRI T2-weighted MRI

Different clinical centers

Different scanning parameters

Examples and reading materials

- Unsupervised Cross-domain Image Classification by Distance Metric Guided Feature Alignment (https://link.springer.com/chapter/10.1007/978-3-030-60334-2_15)
- Mutual Information-Based Disentangled Neural Networks for Classifying Unseen Categories in Different Domains: Application to Fetal Ultrasound Imaging (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7116845/)
- Synergistic Image and Feature Adaptation: Towards Cross-Modality Domain Adaptation for Medical Image Segmentation (https://ojs.aaai.org/index.php/AAAI/article/download/3874/3752)
- Unsupervised domain adaptation in brain lesion segmentation with adversarial networks (https://link.springer.com/chapter/10.1007/978-3-319-59050-9_47)