Artificial Intelligence in Medical Imaging for Precision Medicine

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Talk overview

- Medical imaging in Precision medicine
- AI Applications in imaging for precision medicine
  - *Individual subject-level*
  - *Population-level demographic factors-driven*
- Challenges in AI tool development
  - *Data/label limitations*
  - *Domain shifts across centres and scanners*
  - *Data sharing and privacy*
- Opportunities/future directions

What is precision medicine?

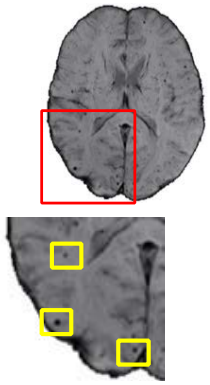
- Personalized care
  - subject's medical history / lifestyle factors
  - Disease biomarkers
  - Genetic factors

- Patient complains about mood changes and gait disturbances
  - Could be symptoms of many disorders
  - Knowing additional information could help (e.g., hypertension, lesions in specific regions, smoking/stress etc.)

Medical imaging in precision medicine

- Early diagnosis
  - Routine scans, *incidental findings*
- Differential diagnosis
  - Differentiating diseases with similar symptoms
- Screening and treatment planning
  - *Longitudinal analysis*, response to drug administration
- Monitoring and predictive analysis
  - Disease severity prediction, *pre- vs post-surgery analysis*
- Data-driven and hybrid decision making
  - Using scans and *imparting domain (clinical) knowledge/factors*
- Further understanding of disease conditions
  - Large-scale epidemiological studies, *population-level modelling*

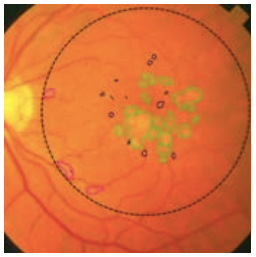
AI application in imaging for precision medicine



Early diagnosis

Detection of cerebral microbleeds

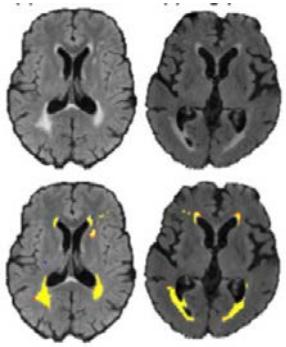
Early sign of neurodegeneration of various cerebrovascular diseases

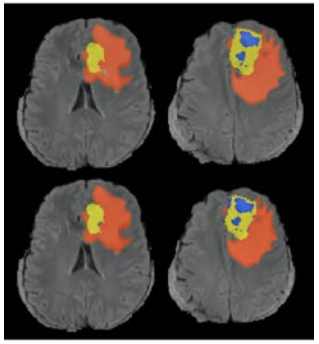


Screening & monitoring

Screening diabetic retinopathy and macular degeneration

Scoring based on early, intermediate and late signs





Extraction of imaging biomarkers for diseases

Segmentation of white matter hyperintensities and brain tumor lesions – estimate the lesion load

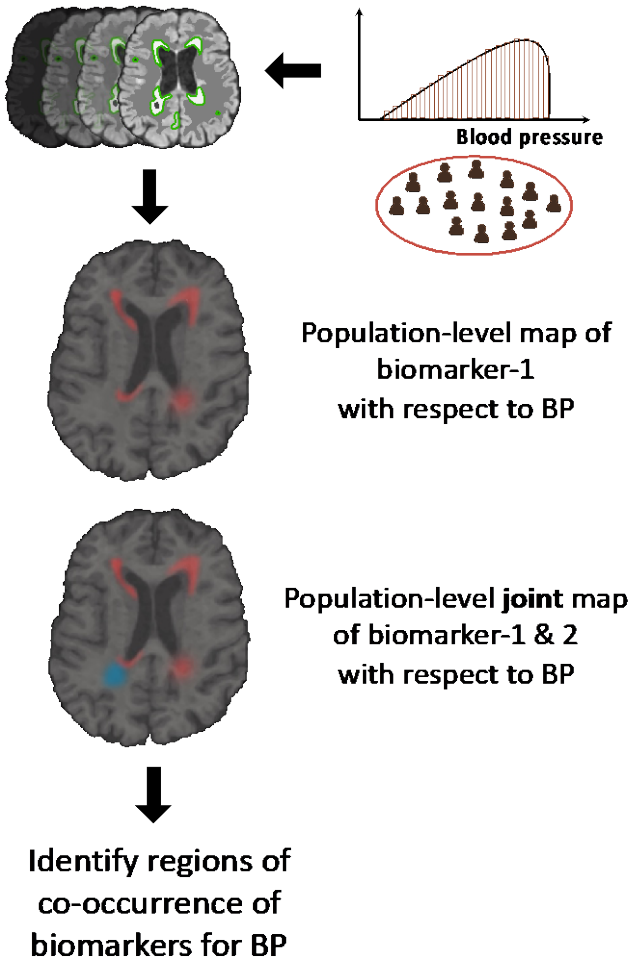
Useful to investigate their distribution and rating to get more information on their incidence.

V Sundaresan et al. NeuroImage, 2019a
V Sundaresan et al. ISMRM, 2020
V Sundaresan et al. Medical Image Analysis, 2021
V Sundaresan et al. OMIA, MICCAI, 2015
V Sundaresan et al. IEEE EMBC, 2015
V Sundaresan et al, OHBM, 2018, 2019

Demographic factors-driven precision diagnosis

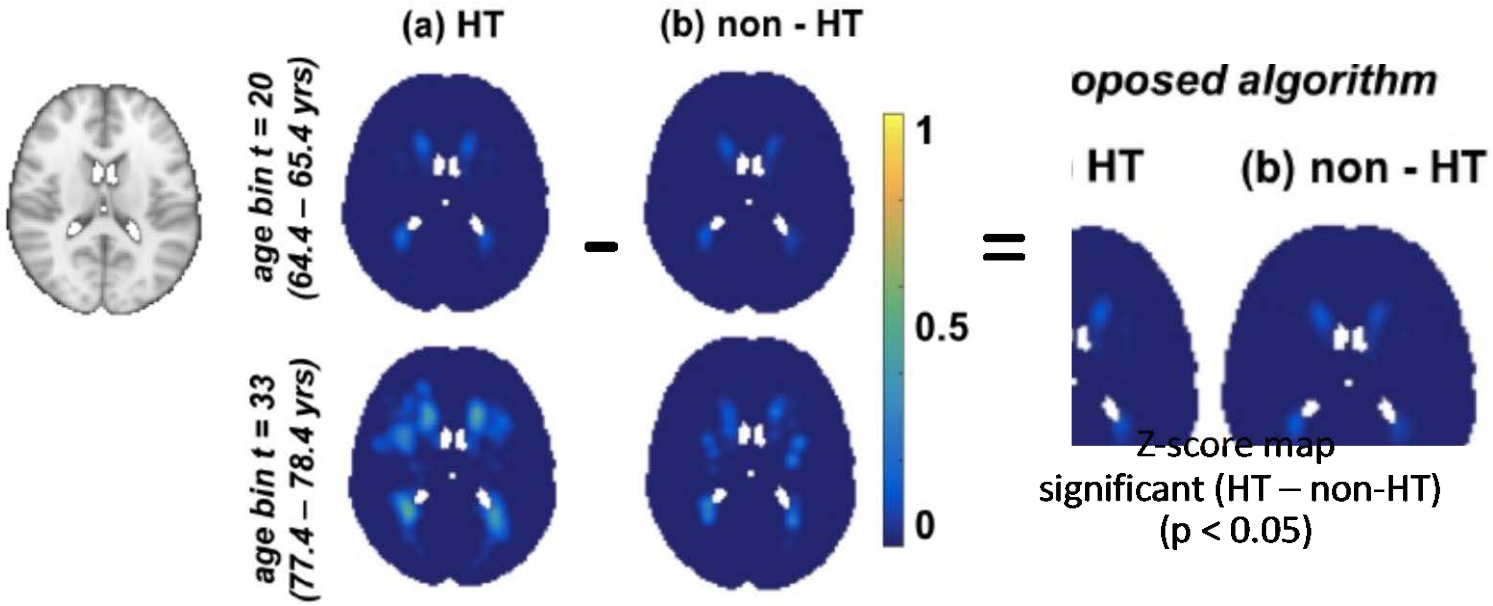
Modelling the distribution of anomalies within a population

Useful in obtaining a population-level prior for specific diseases



Modelling white matter lesion distribution within a population

biobank uk Largest brain imaging database, currently ~40,000 subjects scanned, with the target of 100,000 subjects. Big data - total database size: 500 TB.

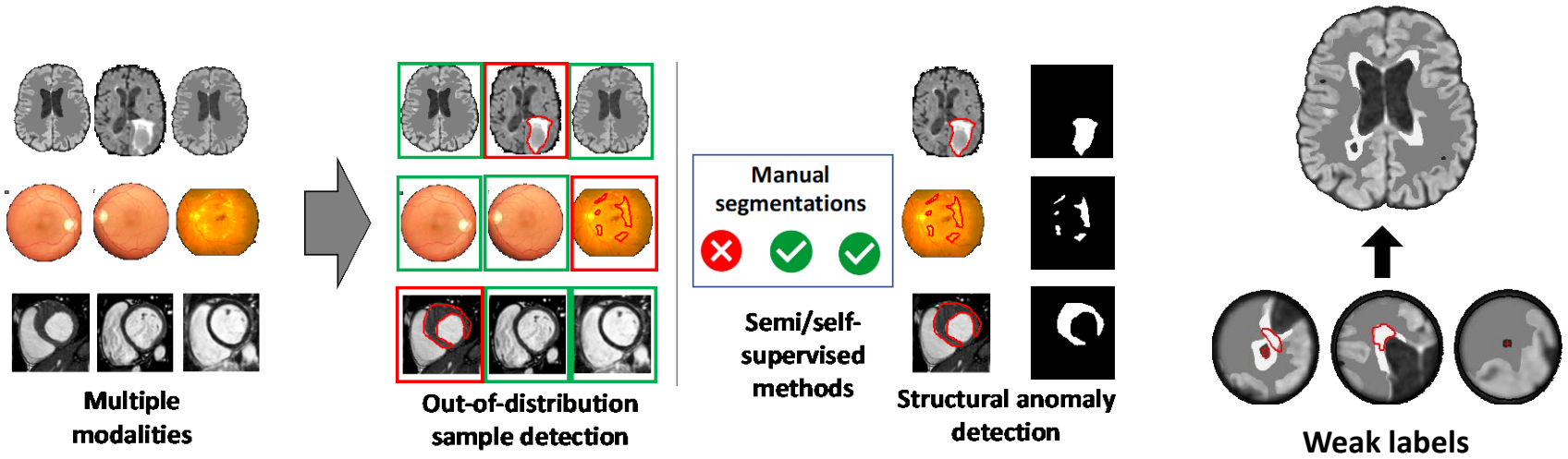


V Sundaresan et al. NeuroImage 2019b

Challenges in AI tool development

Data/label limitations

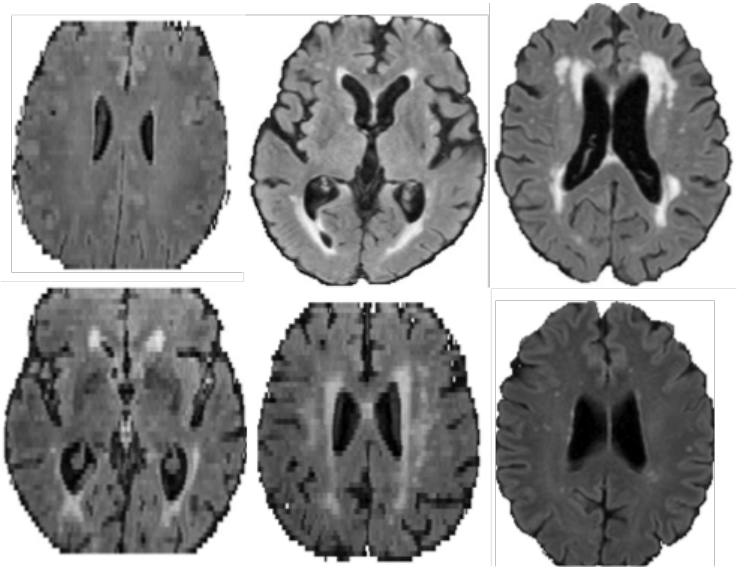
- Medical data is sensitive and difficult to obtain, have to be anonymized
- Manual annotation of medical imaging is time-consuming and expensive
- Self-/semi-supervised techniques

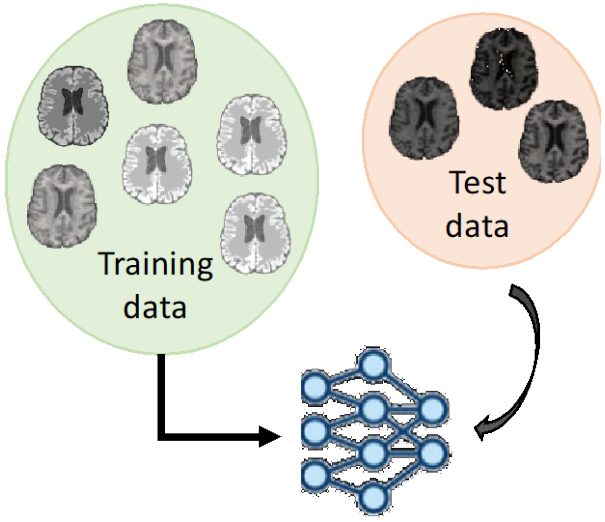


V Sundaresan et al, IEEE ISBI 2022

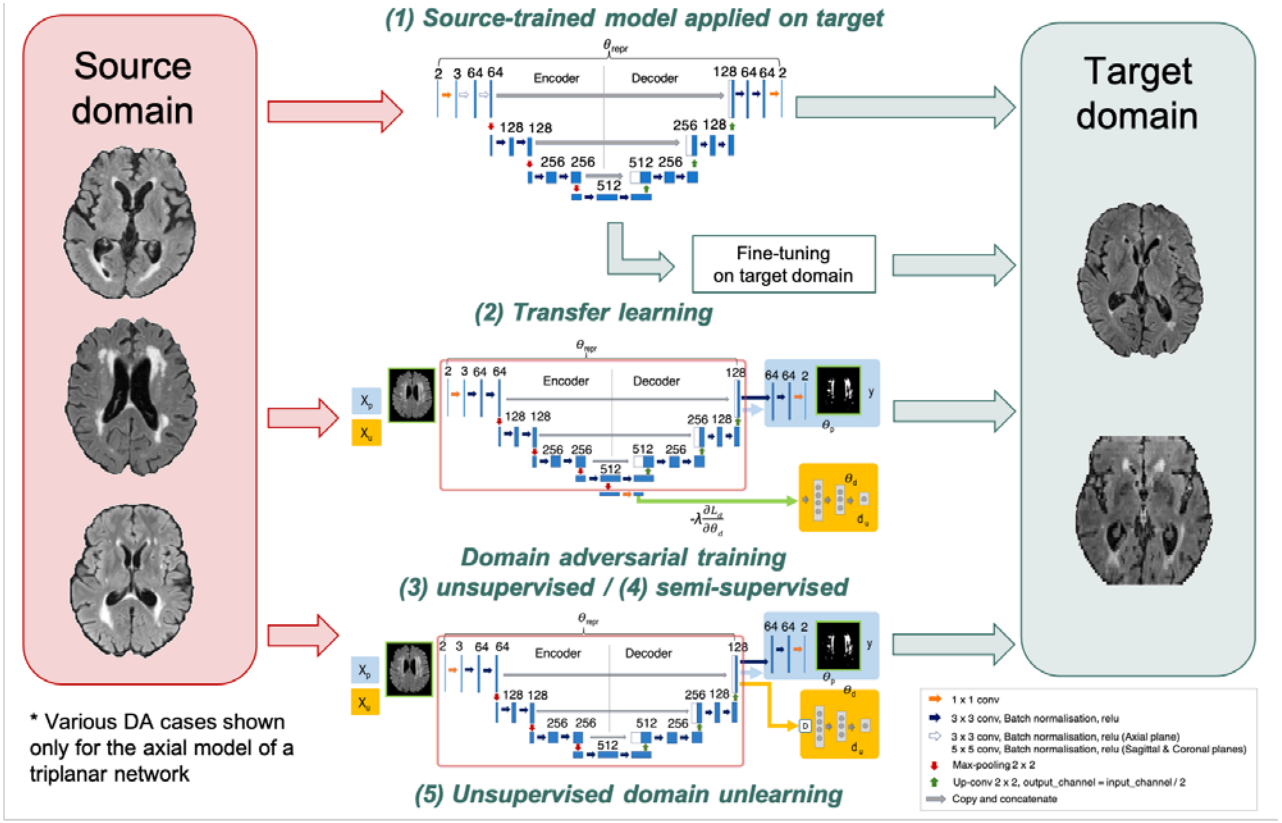
Data domain shifts in multi-centric data

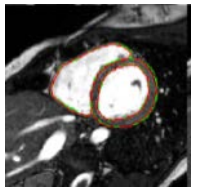
Domain adaptation: Transfers knowledge from source to target domain by leveraging domain invariant features to reduce domain shift.





Comparison of domain adaptation (DA) techniques for neurodegeneration lesion segmentation





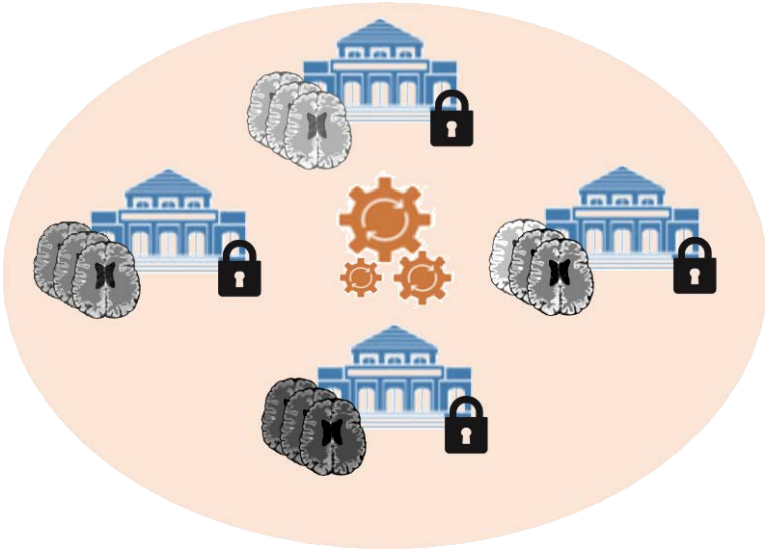
Multi-Centre, Multi-Vendor and Multi-Disease Cardiac MR segmentation

Classification of X-ray images from different domains

J A Acero, V Sundaresan* et al. STATCOM MICCAI, 2020*
V M Campello et al. IEEE Trans. On Medical Imaging, 2021
V Sundaresan et al. Medical Image Analysis 2021b

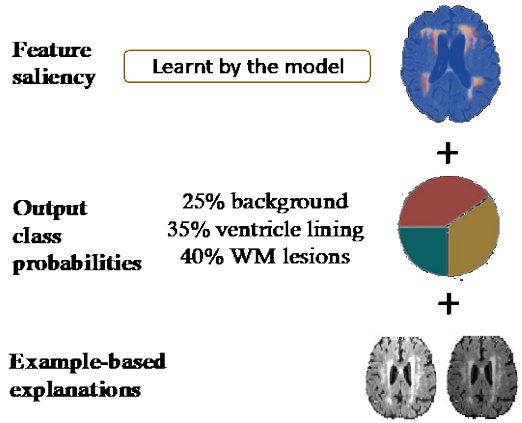
Data sharing and privacy protection

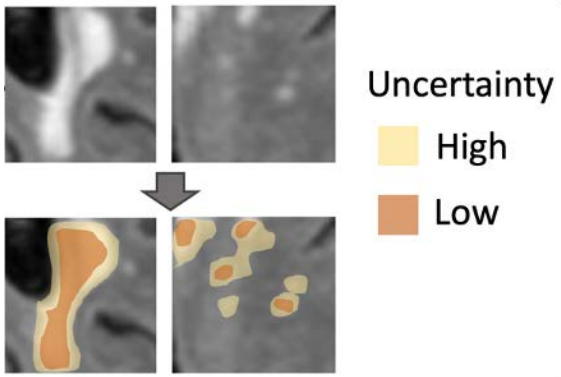
- Federated learning:
  - Preserves data privacy
  - Model training done individual centres rather than sharing data
  - Aggregate model parameters *centrally* from individual models
- Emerging areas:
  - Addition of unseen centres in FL, cross-modal domain adaptation, missing modalities



Opportunities/future directions

- Interpretability and Trust – explainability
  - Including clinicians in the loop
- Out-of-distribution detection
  - Open-world anomaly detection (open-set recognition)
  - Integration within a federated learning set-up
  - Anomaly informed precision diagnosis (incidental findings)
- Accurate extraction of underexplored biomarkers
  - Disentanglement of source (e.g., pathological vs scanner-induced)
  - Characterization and reporting





THANK YOU!

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