# How to enable transfer between DL networks on large 3D data?

## 4th Round Table on AI @ DESY

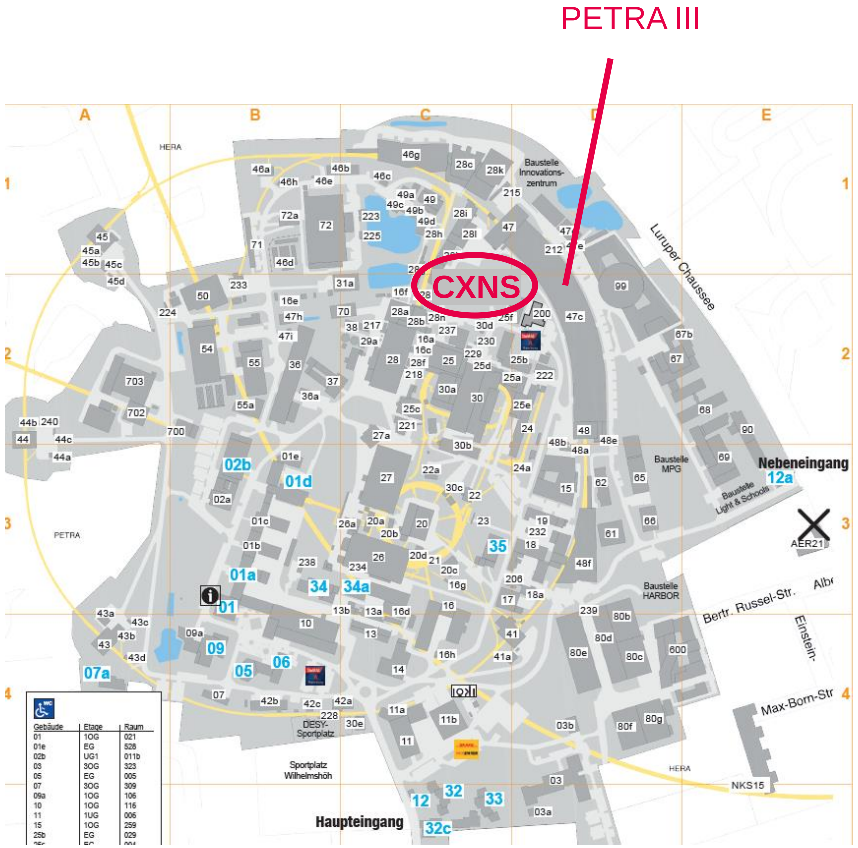
**Christian Lucas**

Hamburg, 3 Dec 2021

Helmholtz-Zentrum hereon

# Metallic Biomaterials, Imaging and Data Science

## Who? Where? What?




### Helmholtz-Zentrum Hereon, Geesthacht

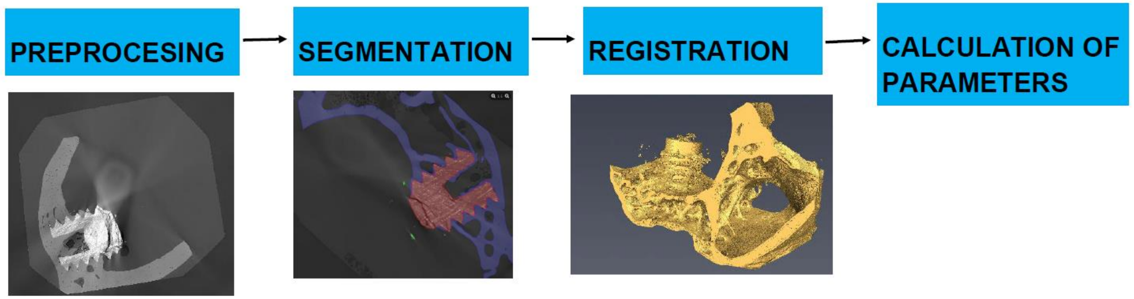
- at PETRAIII (e.g. IBL @ P05) using X-ray micro/nano tomography for materials
- outstation on DESY campus (CXNS building)

### Institute of Metallic Biomaterials (Prof. Regine Willumeit-Römer)

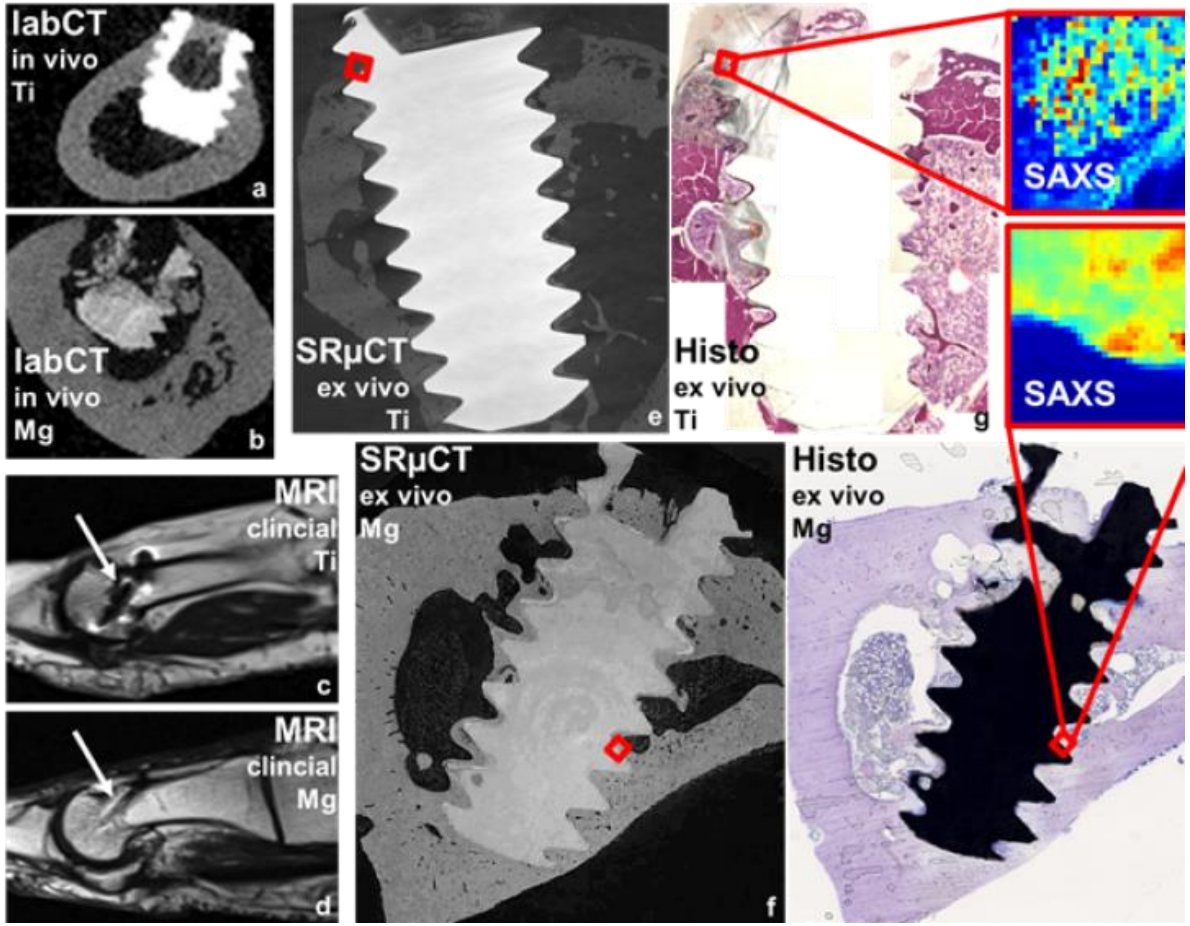
- medical implant materials: based on titanium/magnesium
  - improve biocompatibility, adapt to mechanical bone properties
  - alloys that degrade over time in human body
  - add pharmaceutically active elements for therapeutic effects

### Imaging and Data Science Department

- image processing for analysis of degradation samples



# Multi-task Deep Learning for Large-scale Multimodal Biomedical Image Analysis (MDLMA)




Yet another beamtime/project…

**Artifact reduction?**

**Segmentation?**

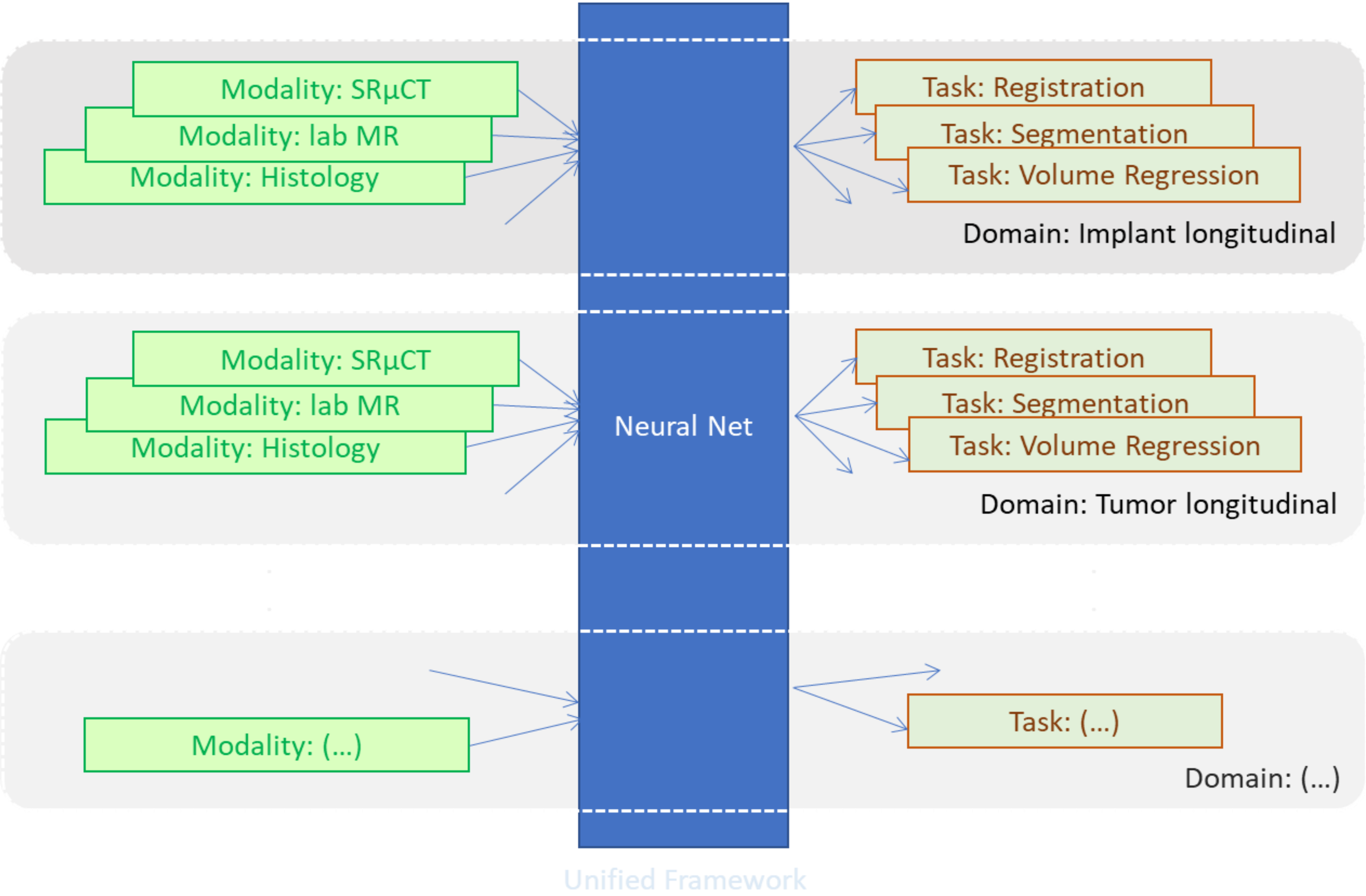
**Registration?**

Do not reinvent the wheel each time!
(i.e. reduce ML training)

→ **Need a common/generic foundation…**

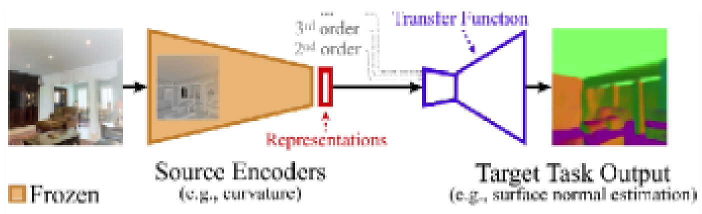
# Handle a selection of multiple modalities/tasks/domains

## Common/Generic unified approach?



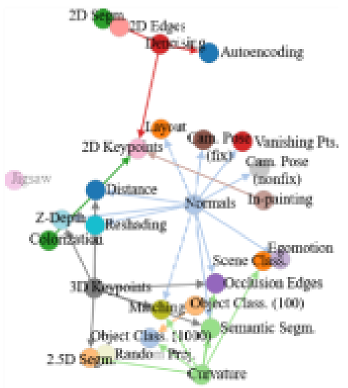
# Disentangled representations

## Basis for many transfers between modalities, tasks, etc.



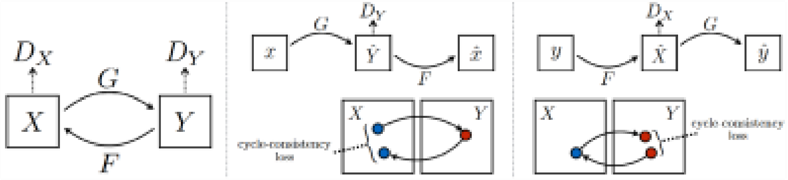

Transfer Function. We use one or multiple source tasks to predict a target task's output.

Zamir et al. (2018) Taskonomy: Disentangling Task Transfer Learning

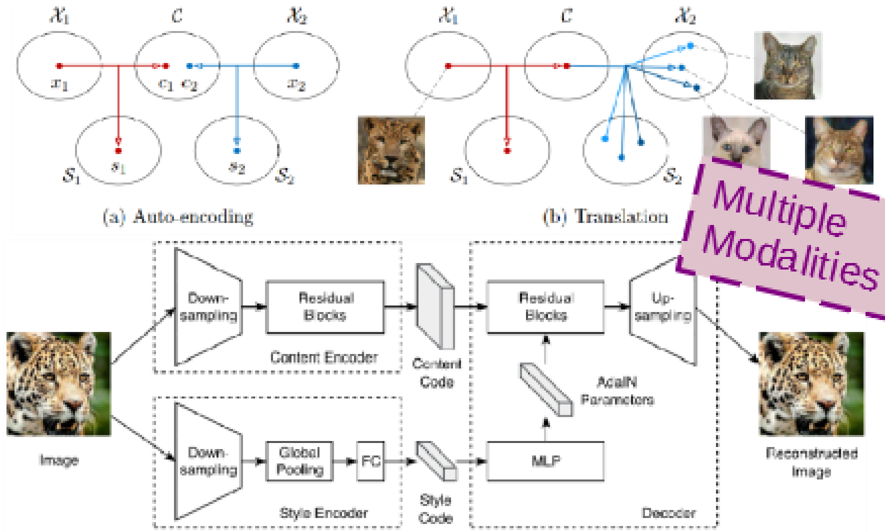



Multiple Tasks

General disentanglement trick:

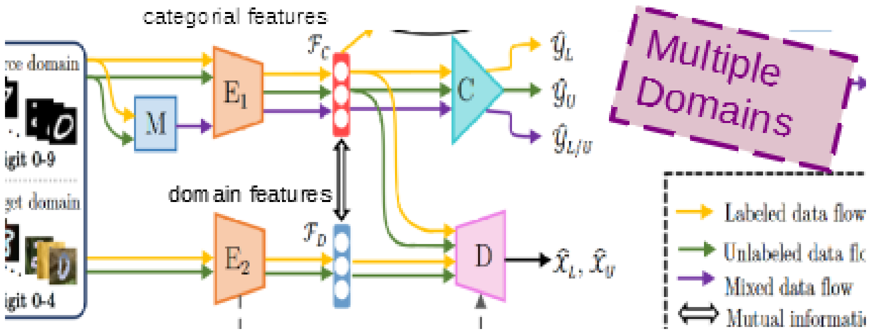



Zhu et al (2017) Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks




Multiple Modalities

Huang et al (2018) Multimodal Unsupervised Image-to-Image Translation (MUNIT)




Multiple Domains

Meng et al. (2020) Learning Cross-domain Generalizable Features by Representation Disentanglement



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# Disentangled representations
## Challenges for a unified network

<u>Goal</u>: Training end-to-end to benefit from all available information

**“It‘s the *memory*, stupid!“**

Disentangling representations: many encoders/decoders, complex nets
→ increasing dependency graph (e.g. store many intermediate results)

Synchrotron tomography: HIGH resolution!
→ 2048x2048x2048 32-bit image exceeds Nvidia V100‘s 32GB RAM

Registration tasks require full image information (find correspondences)
→ full image representation (not patches)

… sums up to a **HUGE** memory demand

**Parallelization and precision reduction are – by far – not enough!**

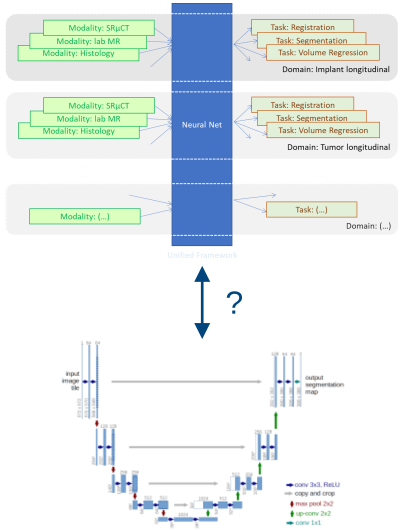
# **Exploit high resolution information**
## & multi-modal/multiple task information

<u>Idea</u>: Separation between

*low-resolution* but complex unified network (3D full representation) trained on all modality and task

and

*high-resolution* specialized but less complex networks (2D patch) trained specific modality and task (e.g. SRμCT segmentation)




**How to transfer between both (model-agnostic) to fine-tune?**

- Ensemble Fusion
- Knowledge Distillation transfer
- Cross-resolutional attention

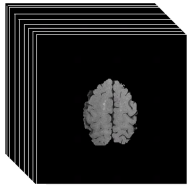
…

# Knowledge Distillation

## Transfer *soft* target knowledge

Exploit information about soft target (logits) of a teacher network

First experiments on a public 3D brain tumor dataset:

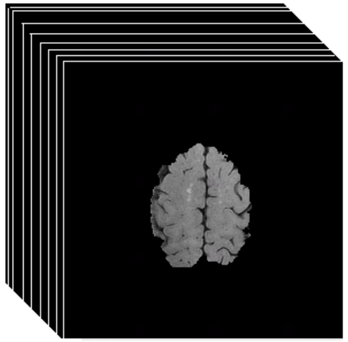


all modalities (low res)

Teacher CAE 3D

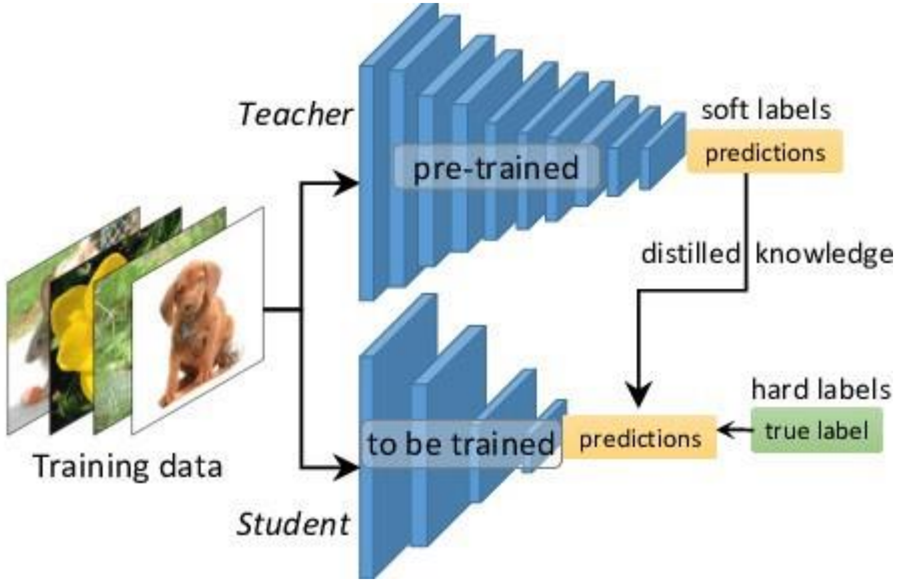
logits divergence

single modality (high res)

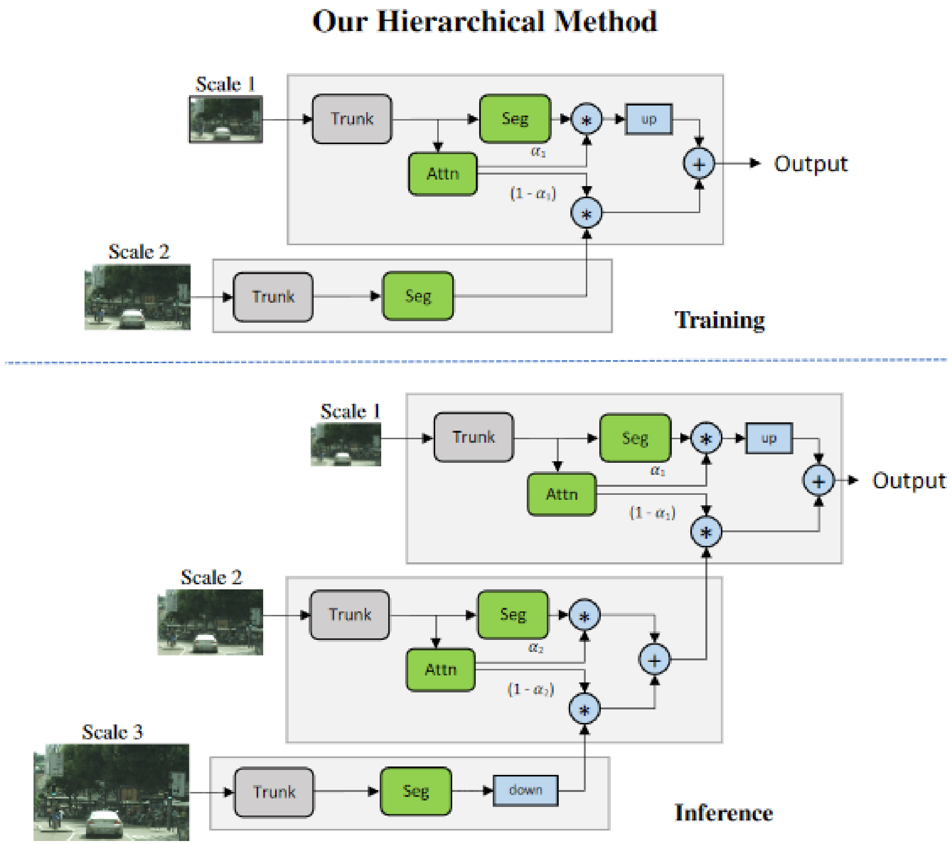


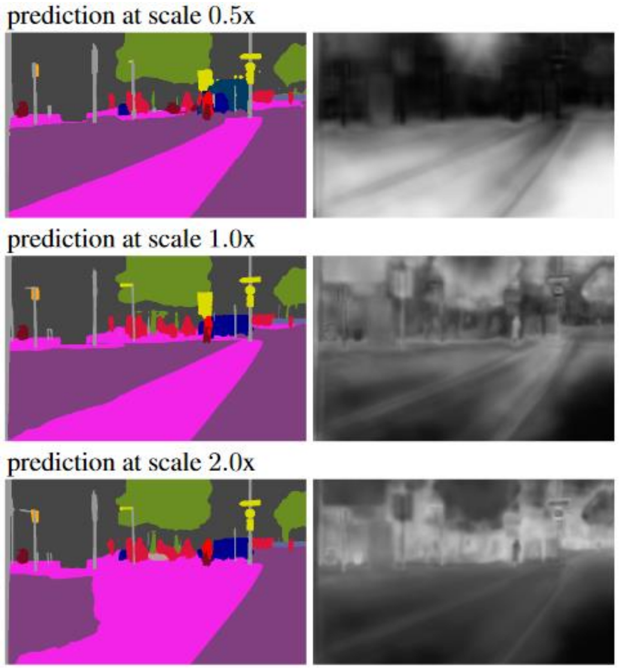
Student U-Net 3D

**Results on 3D ok, but not sufficient for 3D to 2D transfer!**



# Current work-in-progress
## Attention fusion approaches across resolution scales

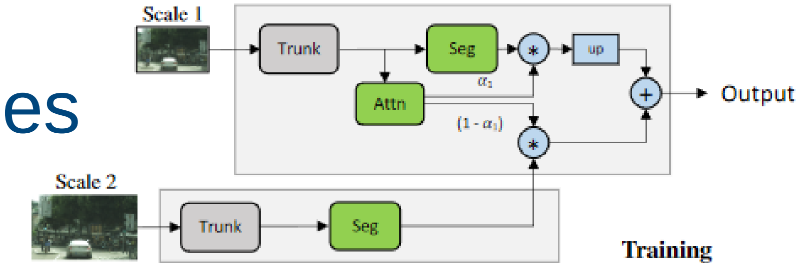


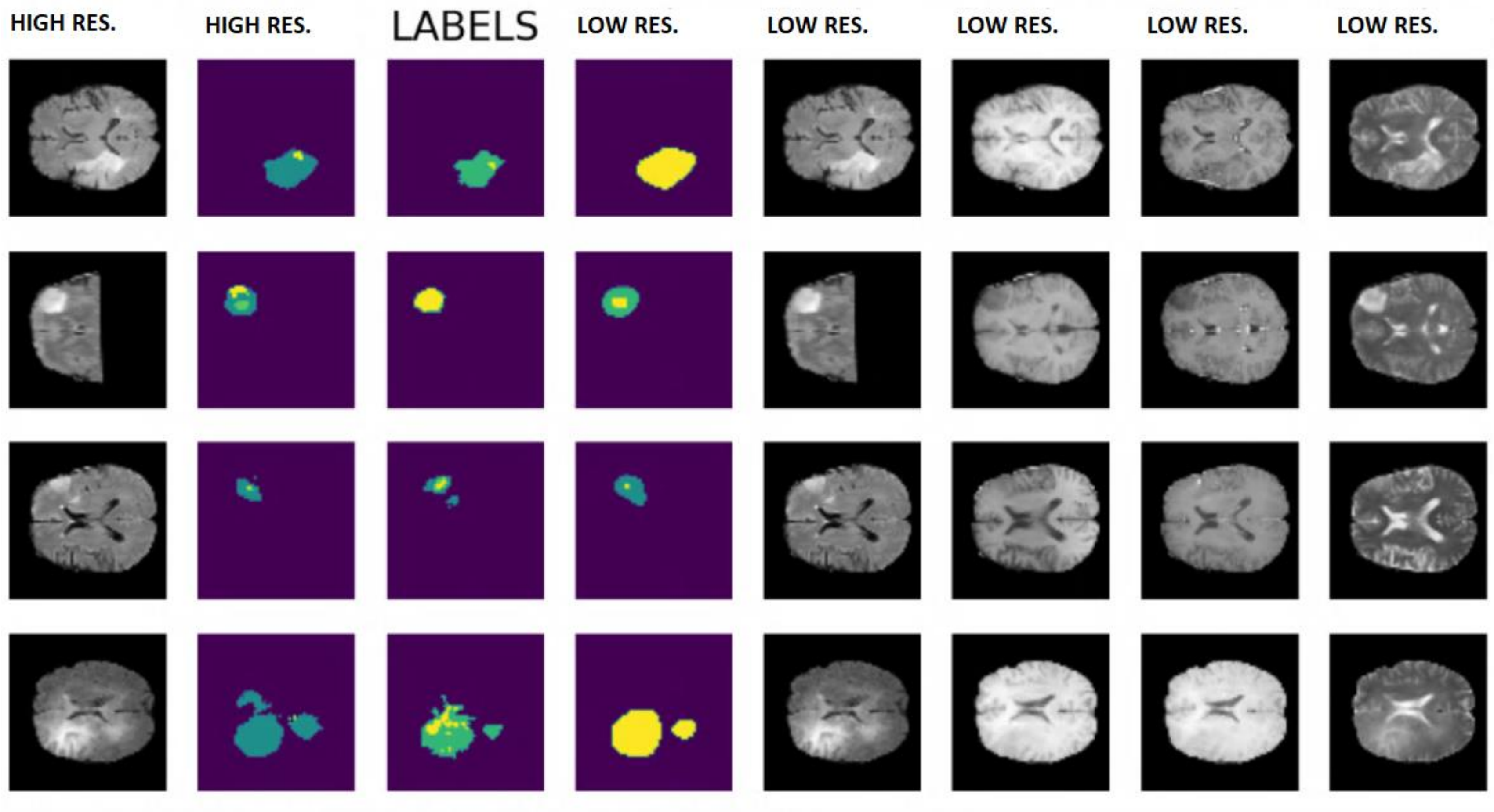




Tao, Sapra, Catanzaro (Nvidia, 2020): HIERARCHICAL MULTI-SCALE ATTENTION FOR SEMANTIC SEGMENTATION

# Current work-in-progress

## Attention fusion approaches across resolution scales




Scale 2

Scale 1

# No sufficient methodology/results yet…

## Similar problems? Facing same contraints with CV?

**If you like to exchange experience, I am pleased to hear from you:**

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