PARACELSUS MEDIZINISCHE UNIVERSITÄT

UNIKLINIKUM SALZBURG LANDESKRANKENHAUS

Optimised intraoperative radiotherapy treatment workflow using machine learning methods

Sara Vockner [1)], Markus Stana [1)], Christoph Gaisberger [1)], Elvis Ruznic [1)], Klarissa Ellmauer [1)], Josef Karner [1)], Mattke Matthias [1)], Franz Zehentmayr [1)], Falk Röder [1)]

1) UK f. Radiotherapie & Radio-Onkologie der PMU, SALK

IORT

High dose of radiation delivered to the tumour or tumour bed during surgery.

Teletherapy

3D imaging modality for determination of:

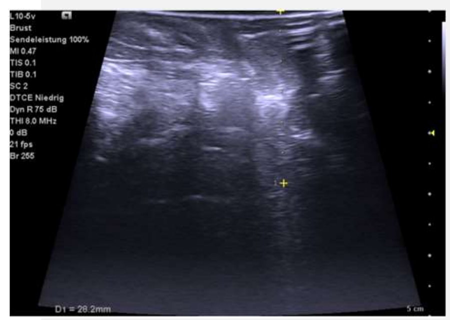
- Target Volumes
- Organs at Risk
- Dose Distribution

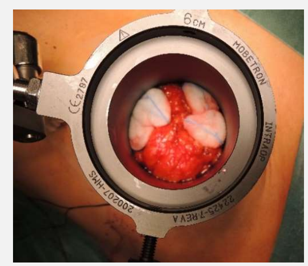
Advantages of voxel-based 3D models:

- Exact geometry
- Density Values

IORT

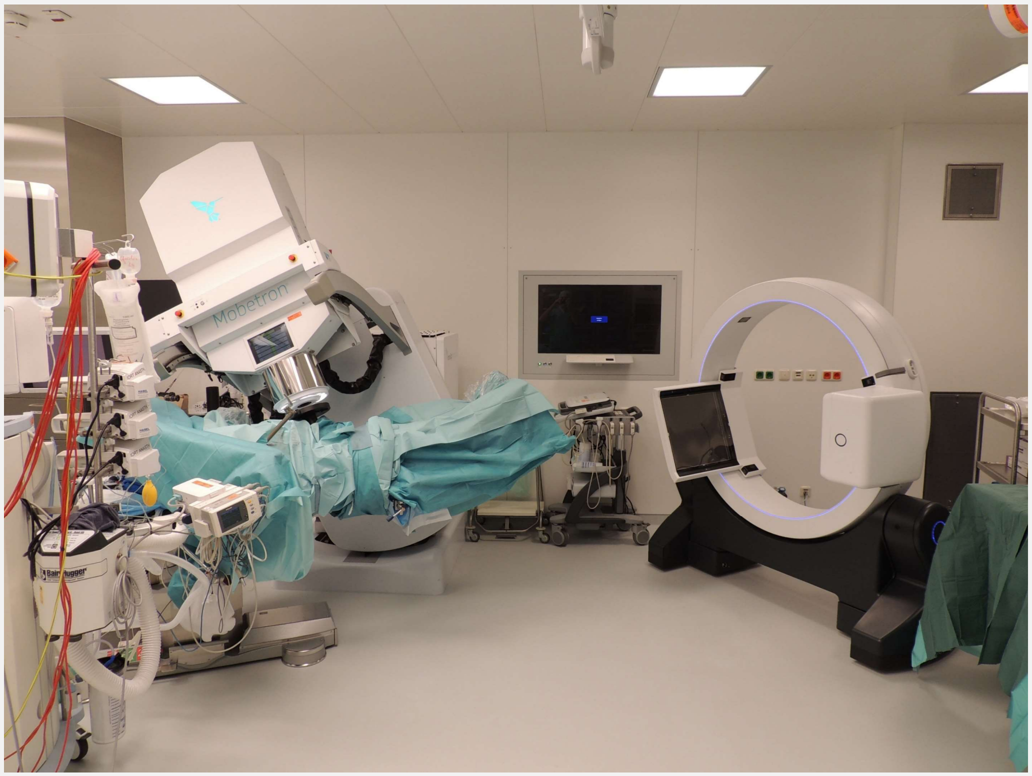
- 2D imaging (sonography) used for estimation of dose distribution





UNIKLINIKUM SALZBURG

Imaging Ring



3D imaging device in operating room:

- Mobile Cone beam CT (CBCT)
  (Imaging Ring-m, medPhoton)
- Dose distribution estimated more specifically
- CBCT scan in treatment position during IOeRT
- First clinic to use IRm for IOeRT

GOAL:

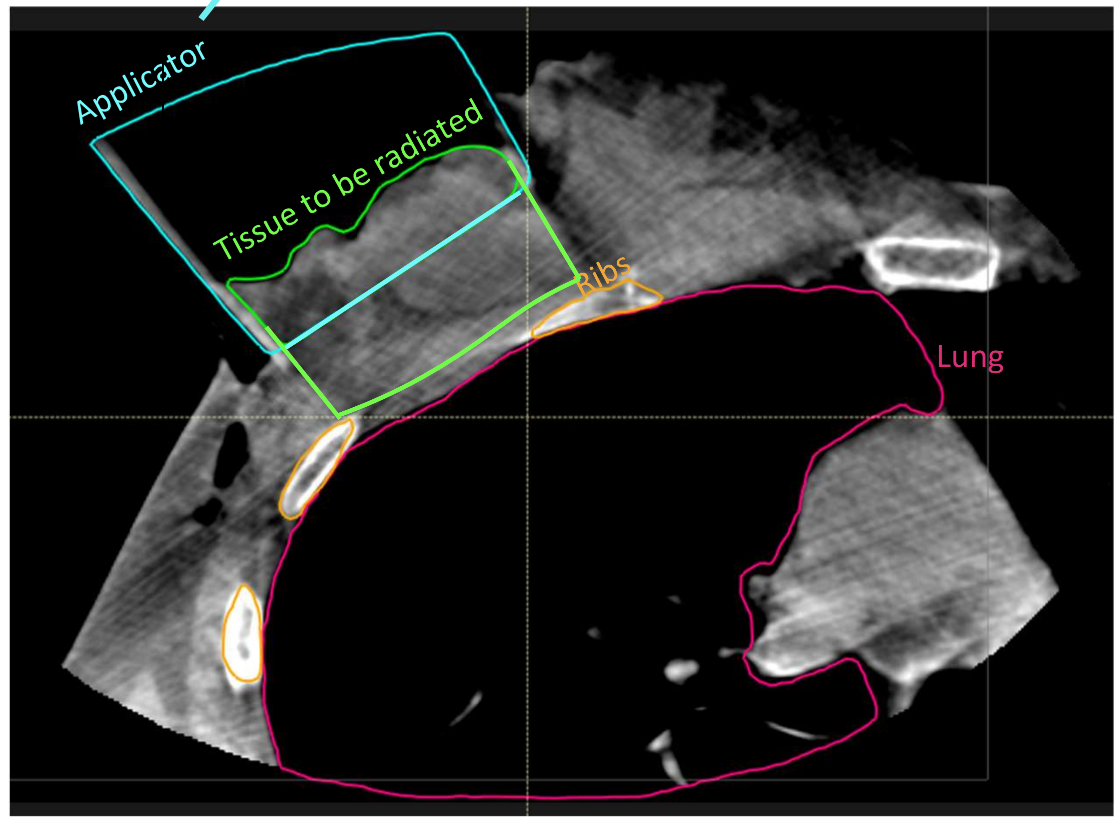
Closing the gap in treatment planning between teletherapy and IORT by leveraging machine learning to streamline the time-consuming process of 3D image-based IORT treatment planning.

Automatic Contouring IORT

- Contours necessary for 3D dose estimation
- Manual segmentation very time-consuming
- Tight time schedule in an operative setting

Implementation of an artificial neural network (ANN) to segment:

- Tube, tissue within tube, lung, ribs



PMU

UNIKLINIKUM SALZBURG

IntraOp

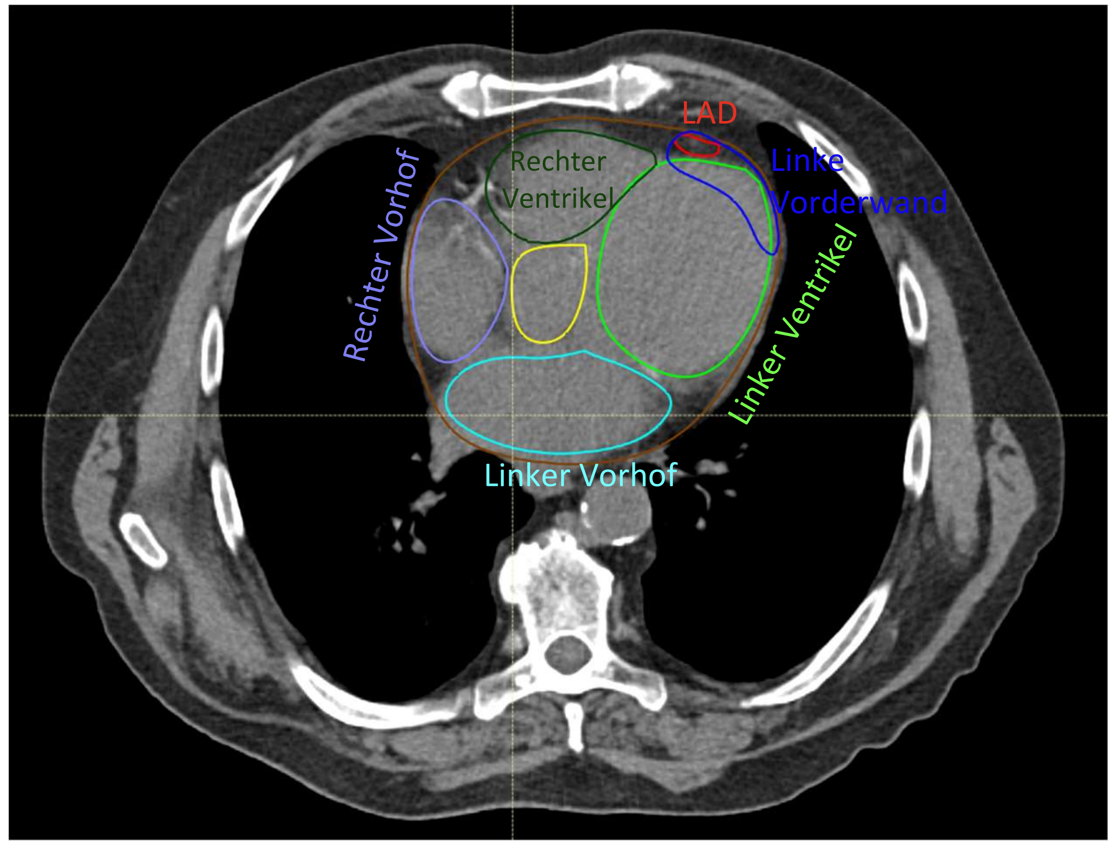
Heart Regions Auto-Contouring

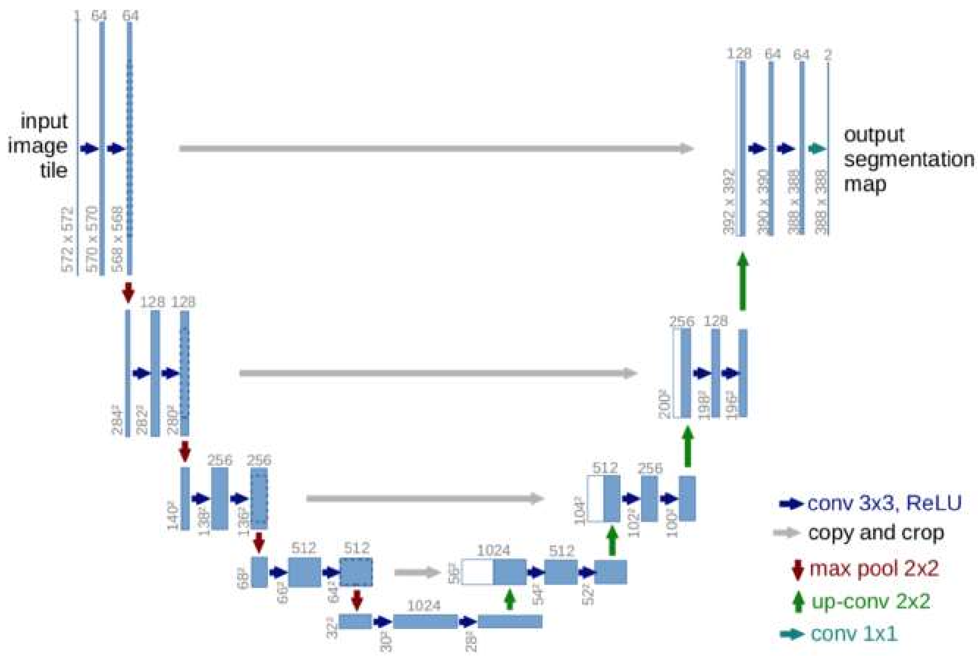
Issue:

Bad image quality of mobile CBCT due to artifacts and variable field of view size

Approach:

- ANN for auto segmentation of heart regions
- Good quality CT images
- Heart regions contours based on knowledge
- Dataset size: 85 patients
- Transfer Learning for CBCTs



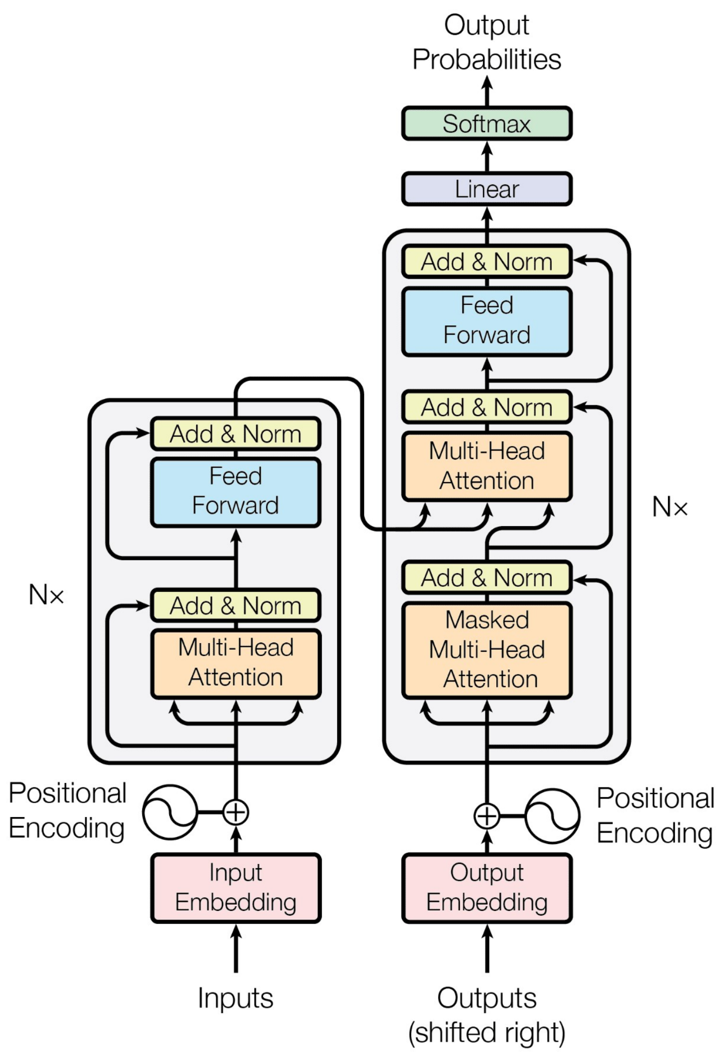


U-Net

+ Captures fine-grained spatial features.
+ Designed for tasks where precise delineation of organ boundaries and local anatomical details is essential.

- Image information only gathered from neighboring pixels
- Fixed convolution kernel size and shape

[1]Ronneberger 2015, U-Net: Convolutional Networks for Biomedical Image Segmentation



Transformer

+ Self-attention mechanism to capture long-range dependencies and global context in medical images.
+ Understanding of relationships between anatomical structures across an entire medical image is crucial.

- $O(n^2)$ time and space complexity in respect to sequence length
- No inductive bias for images

[2]*Vaswani et al., 2017, Attention is all you need*

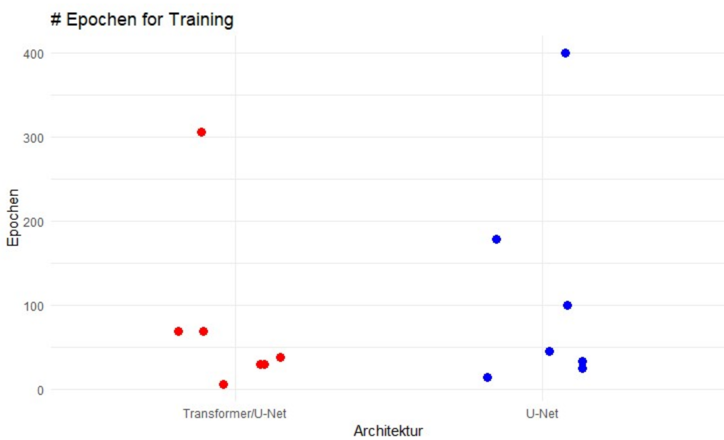
UNIKLINIKUM SALZBURG

IDEA:

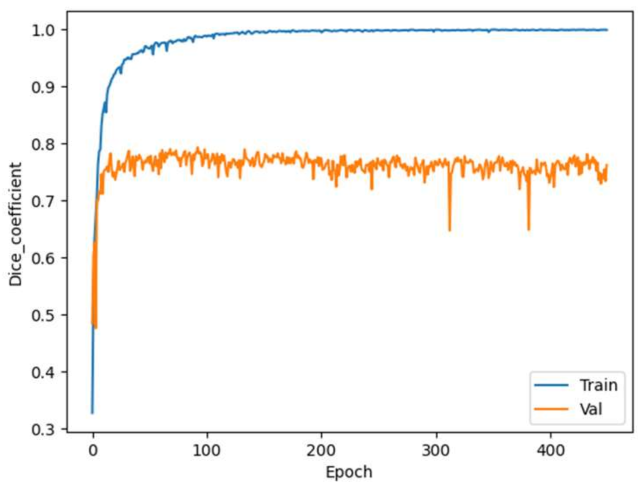
Combination of U-Net and Transformer Network

to enhance quality of CBCT segmentation.

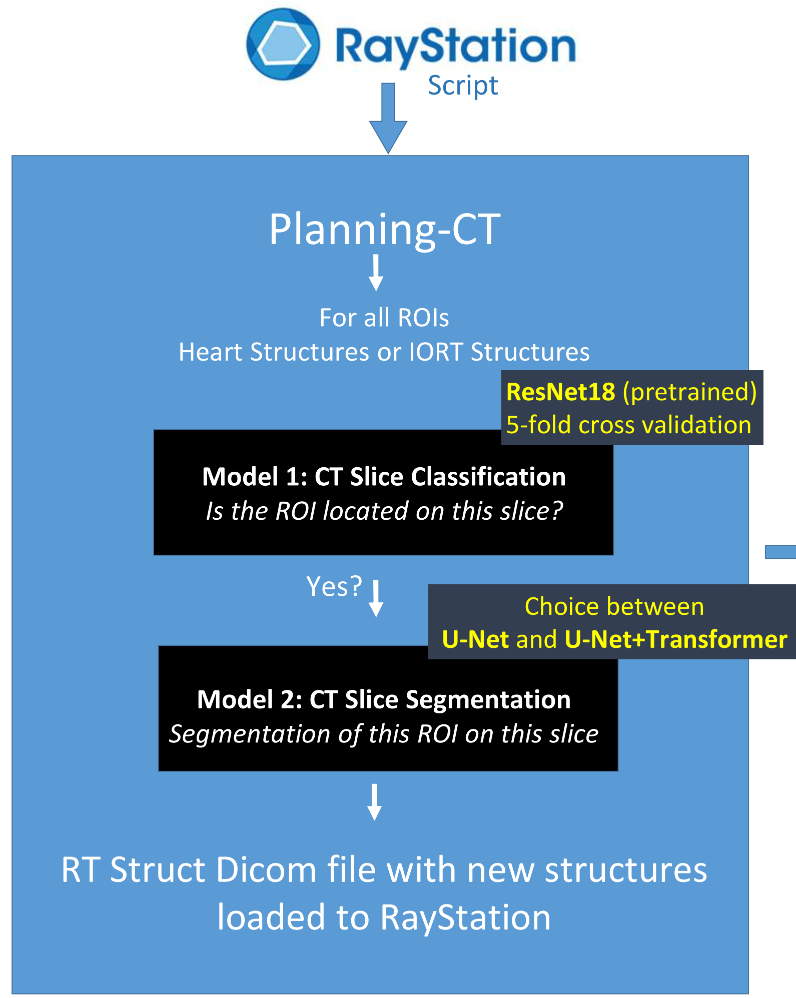
PMU



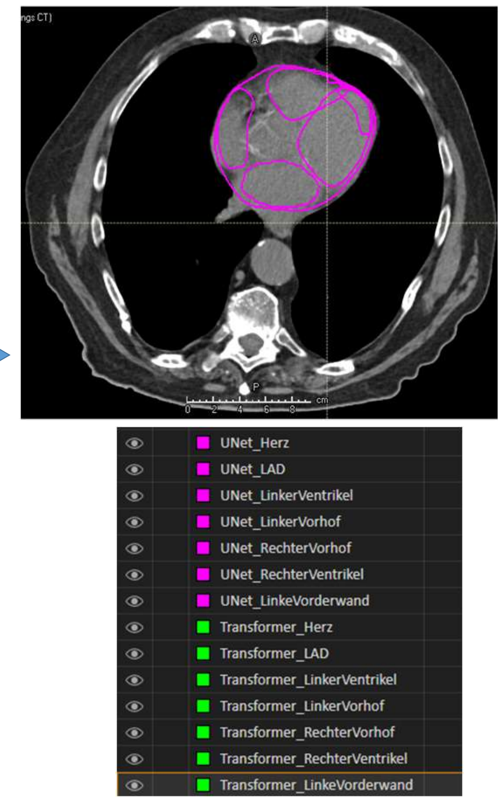
Epochen for Training
Epochen
400
300
200
100
0
Transformer/U-Net
U-Net
Architektur



Dice_coefficient
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
100
200
300
400
Epoch
Train
Val



RayStation
Script
Planning-CT
For all ROIs
Heart Structures or IORT Structures
ResNet18 (pretrained)
5-fold cross validation
Model 1: CT Slice Classification
Is the ROI located on this slice?
Yes?
Choice between
U-Net and U-Net+Transformer
Model 2: CT Slice Segmentation
Segmentation of this ROI on this slice
RT Struct Dicom file with new structures
loaded to RayStation

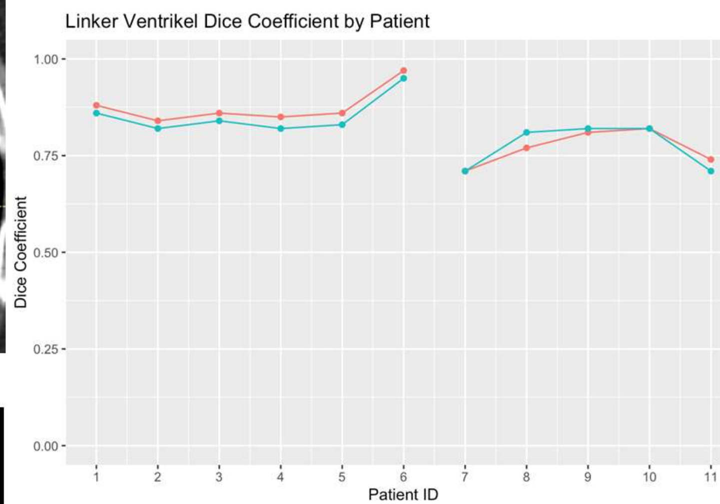


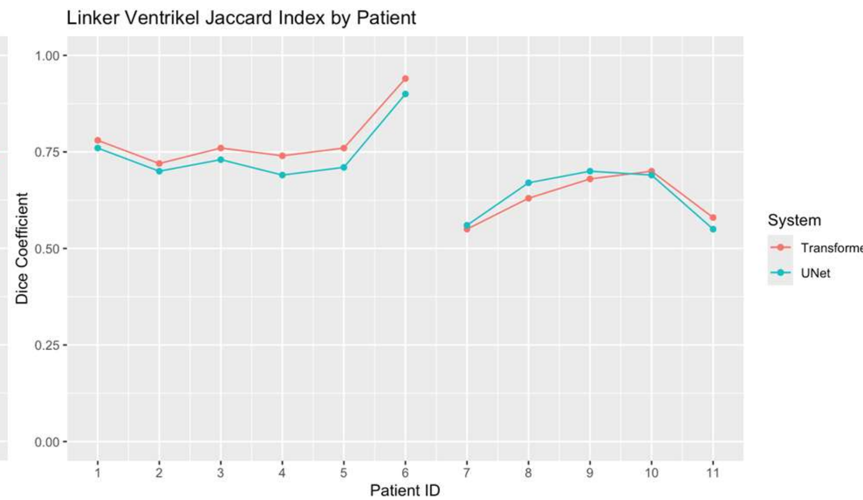
UNet_Herz
UNet_LAD
UNet_LinkerVentrikel
UNet_LinkerVorhof
UNet_RechterVorhof
UNet_RechterVentrikel
UNet_LinkeVorderwand
Transformer_Herz
Transformer_LAD
Transformer_LinkerVentrikel
Transformer_LinkerVorhof
Transformer_RechterVorhof
Transformer_RechterVentrikel
Transformer_LinkeVorderwand

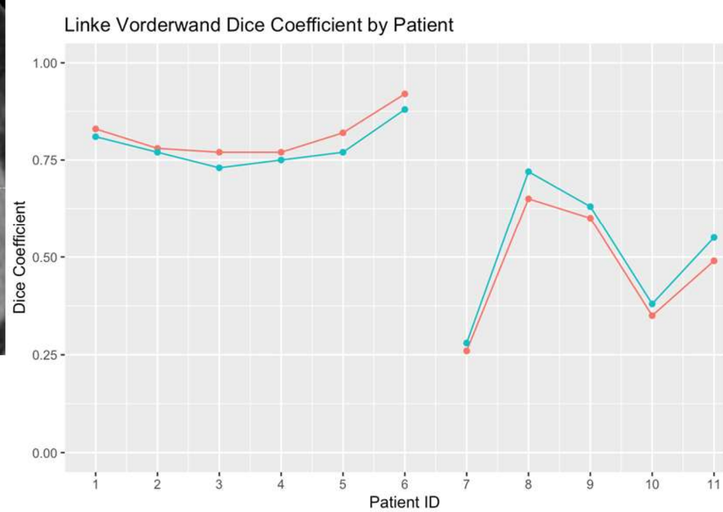
$$Dice(A,B) = \frac{2 * |A \cap B|}{|A| + |B|} \qquad Jaccard(A,B) = \frac{|A \cap B|}{|A \cup B|}$$

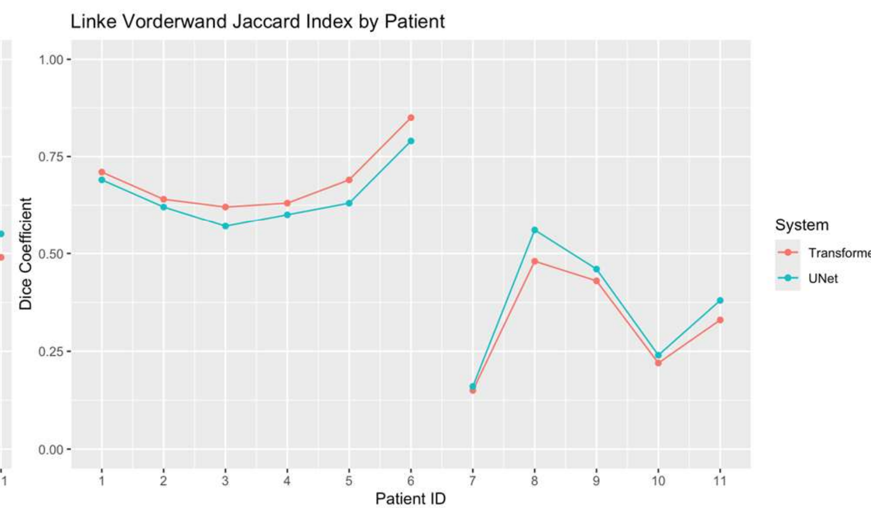
Training patient (nr. 1)

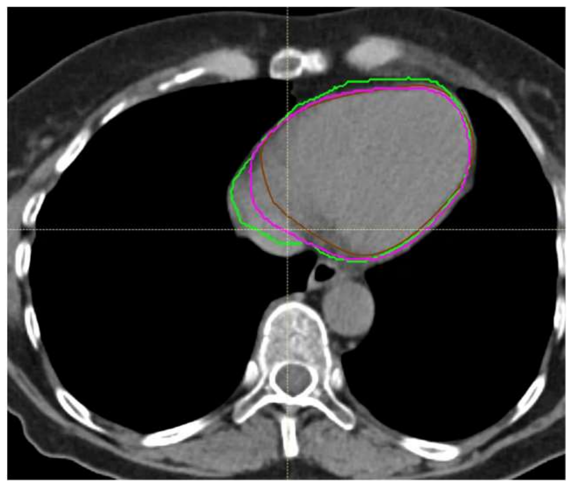
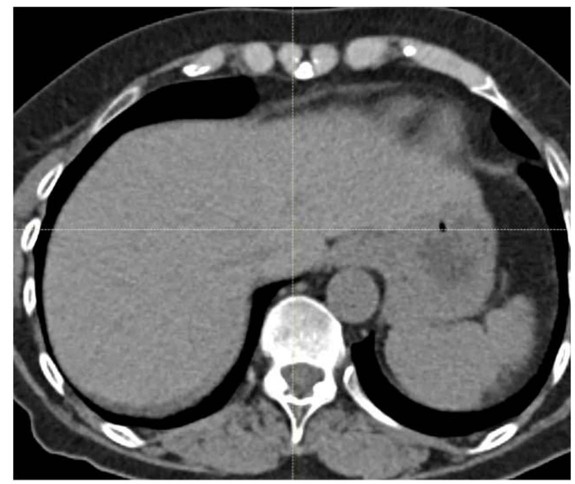
Test patient (nr. 8)

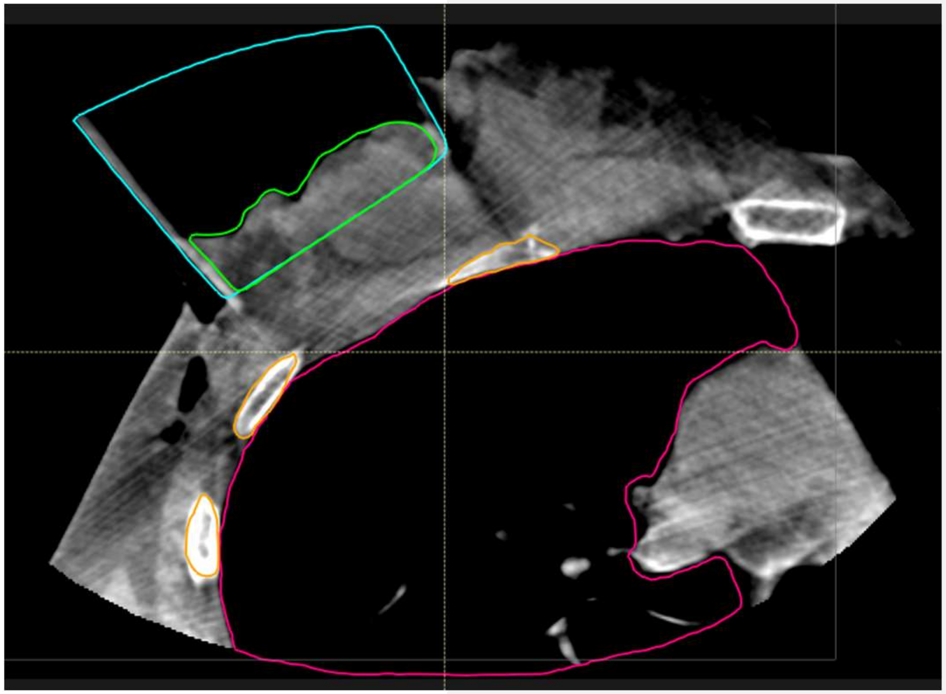








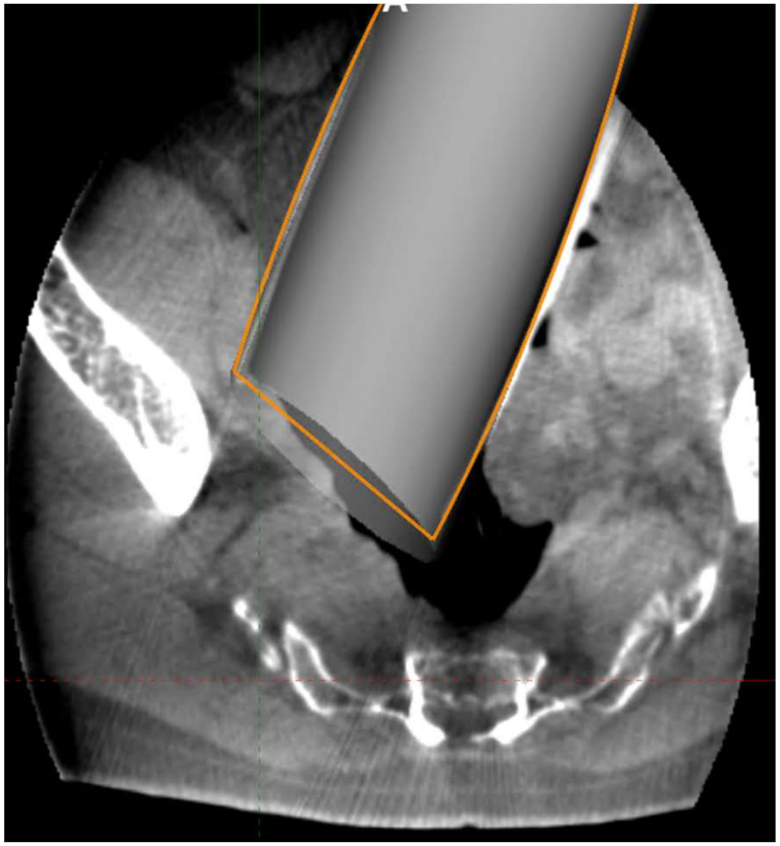


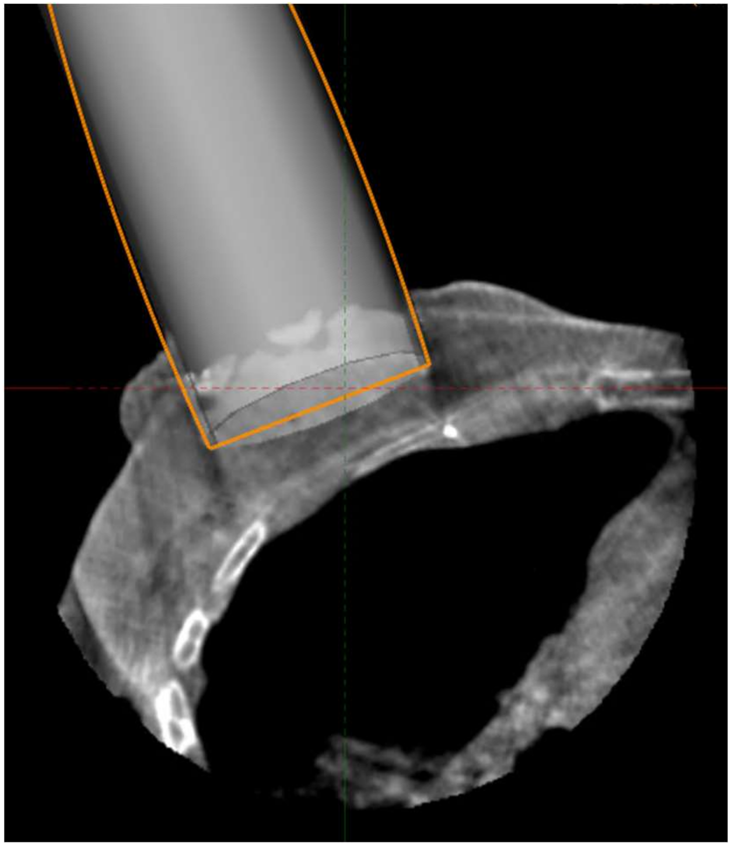
IORT: Automatic Contouring of CBCTs with Transfer Learning

UNIKLINIKUM SALZBURG

PMU

Positioning of radiotranslucent applicator





Positioning of radiotranslucent applicator in TPS

- Correct placement of applicator model in software system Radiance (by GMV)
- Laborious task to align object in 3D image space
- Accurate positioning of applicator through
  - segmentation coordinates of ANN
  - iterative closest point algorithm (ICP)
  - gaussian mixture models (GMM)

UNIKLINIKUM SALZBURG

The synergy of artificial neural networks, advanced image processing and computational methods allows a 3D model-based and less time-consuming treatment planning in an operative setting.

PMU

PARACELSUS MEDIZINISCHE UNIVERSITÄT

UNIKLINIKUM SALZBURG LANDESKRANKENHAUS

Thank you!

Department of Radiotherapy and Radio-Oncology, PMU, SALK