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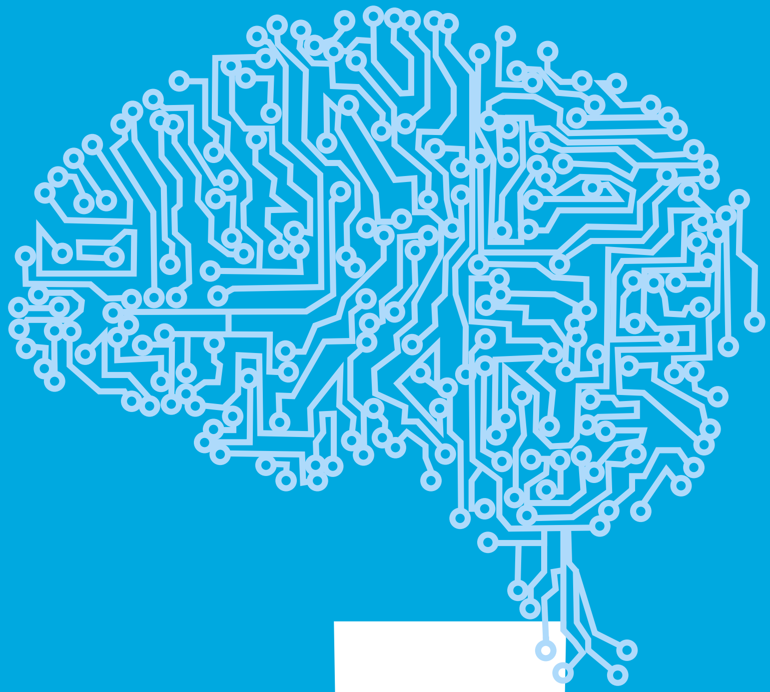

AI for Oncology at Varian – Potential Applications and Opportunities

Applications of Deep Neural Networks in Radiation Therapy Treatment Planning and Image Guidance

September 6, 2018

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Agenda

1. Varian Medical Systems
2. Potential Applications and Expectations
3. AI in Medical Image Processing
4. AI in Automated 3D Image Segmentation
5. AI in Automated Radiation Therapy Planning
6. Conclusion and Questions

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Varian today – a snapshot

Global Leader	$2.6B	7,750	>25
in radiation therapy	FY17 revenues	medical linear accelerators	worldwide training centers

A focused cancer company

4,600+	65+	6,400+	52%
software installs	proton therapy rooms	employees	international order mix

Vision:

A World Without Fear of Cancer

Mission:

To combine the ingenuity of people with the power of data and technology to achieve new victories against cancer

Numerous applications for AI in Radiation Oncology

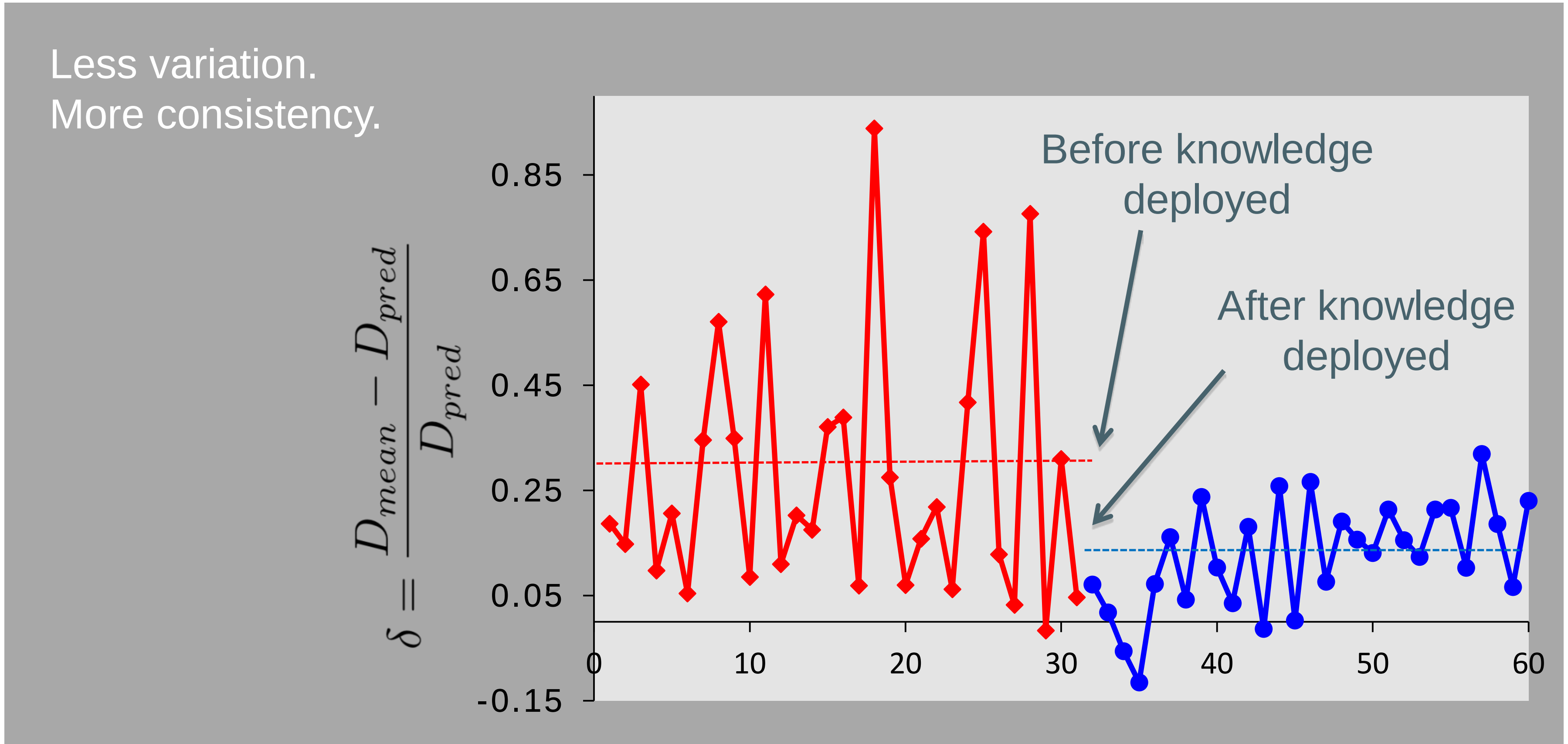
Machine Learning to achieve AI: Augmented Intelligence

- Image processing and reconstruction
- Image segmentation
- Tumor detection & diagnosis
- Patient risk stratification
- 3D dose prediction
- Image registration, matching and registration
- Response assessment
- Patient monitoring, care management
- Biological response prediction
- Clinical decision support (CDS)

Promising early results on external and internal work

RapidPlanTM Knowledge-Based Treatment Planning

Applying Machine Learning to Predict an Achievable Dose Volume Histogram driving the dose optimization



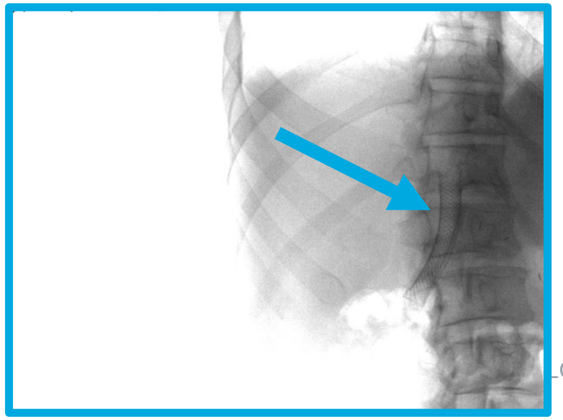
Courtesy Lindsey Olsen, Washington University, St. Louis

Image Processing

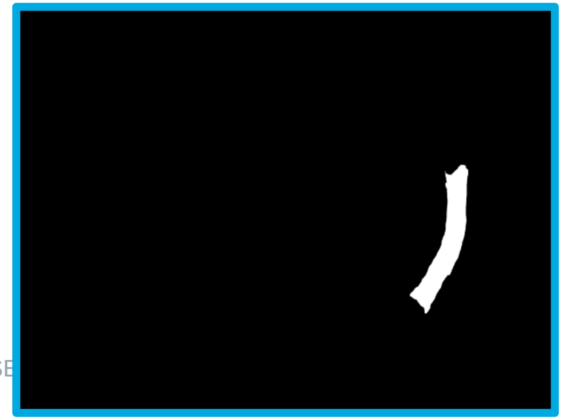
X-ray Projection Images

- Objects:
  - 1 Stent, 3 (different) markers, 6 (different) vertebrae
- Data Set:
  - Training set (750), Validation set (145), Test set (5)
  - Ground Truth semi-automated
- Promising early results
- Clinical refinements required

Stent



Mask



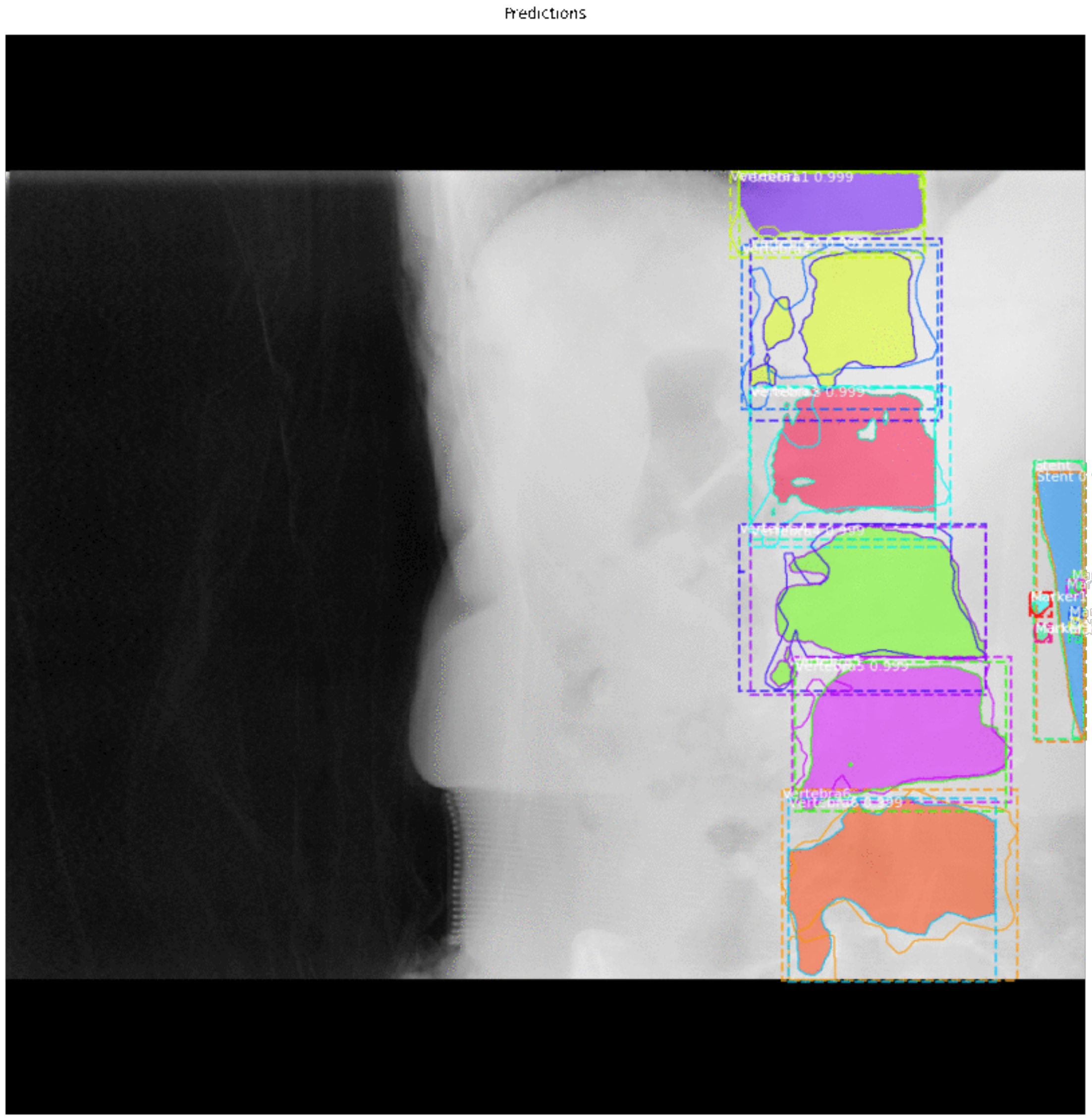
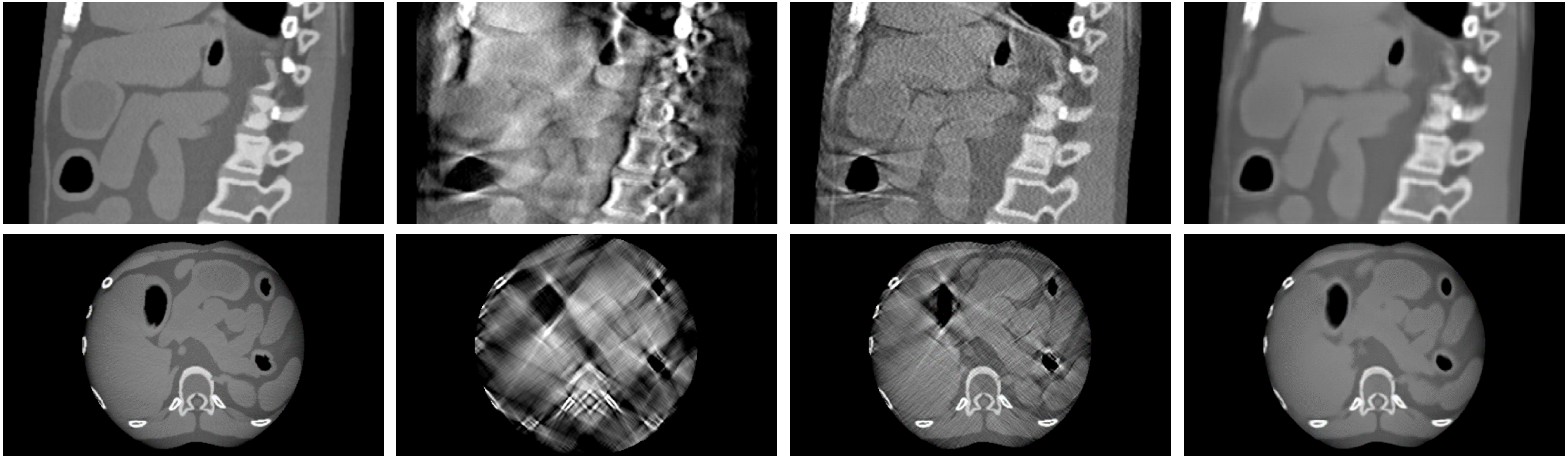


Image Processing

Limited Angle Cone Beam Computer Tomography (CBCT) Image Post-Processing

Ground Truth	Standard FDK Recon	adaptation of Varian MKB 4-D CBCT algorithm	With Machine Learning-based artifact reduction

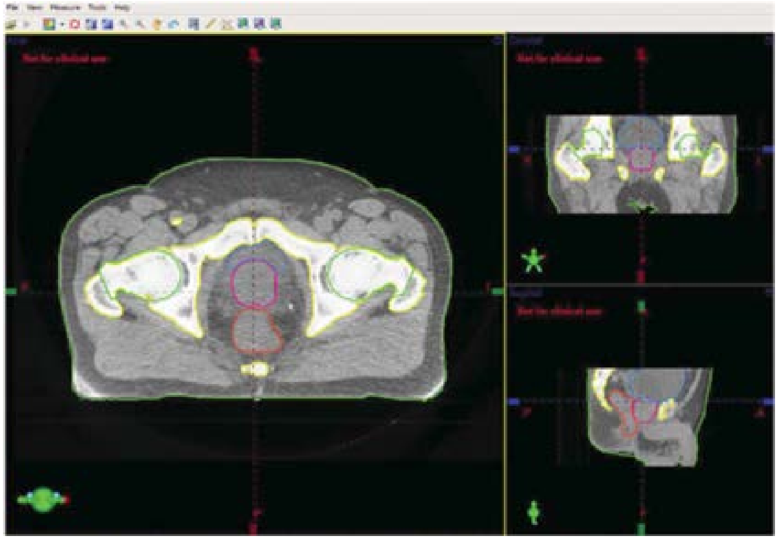


Automated Segmentation

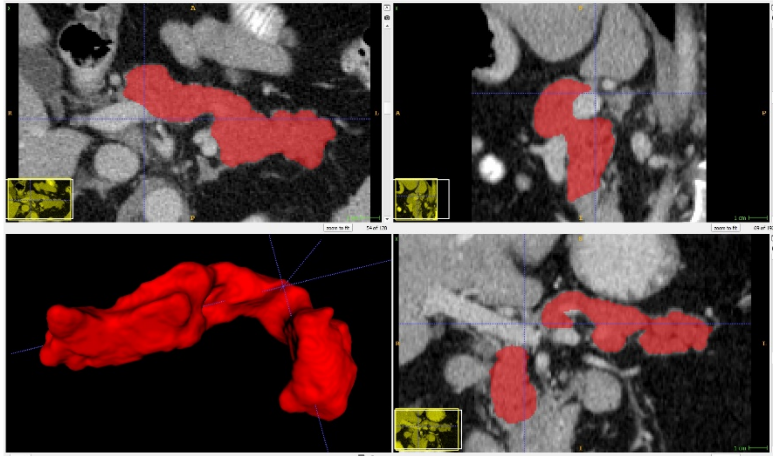
What's the Problem?

- Manual Segmentation of volumetric (CT) images is a prerequisite for radiation therapy planning
  - Dose optimization
  - Dose reporting
  - Dose accumulation
- Manual segmentation is labor intense and dependents on user
- Varian offers automated segmentation tools more than a decade
- Need for fully automate segmentation of Organs at Risk and Clinical Target Volumes
  - Universal Models: Compliant with published consensus guidelines
  - Customizable Models: to center or user preferences
  - Learning Models: Continuously learn from user Corrections

Male Pelvis CT



Pancreas CT



Segmentation Lessons I

Regarding Deep Learning Methods

- Raw clinical datasets are highly variable
  - Define anatomical boundaries for contours
- Clean, curated training datasets are important
  - 50 curated ≈ 250 raw clinical datasets for OARs
  - 350-500 datasets needed to match clinical performance on 99% of cases
- GPU memory is one of the primary technical challenges
- Build the smallest possible model to explain training data
  - Models with 50k and 1.2M parameters are comparable in pancreas
  - Smaller models generalize better to new data (avoids overfitting)
  - Smaller models are easier to train
  - Smaller models infer faster than more complex models

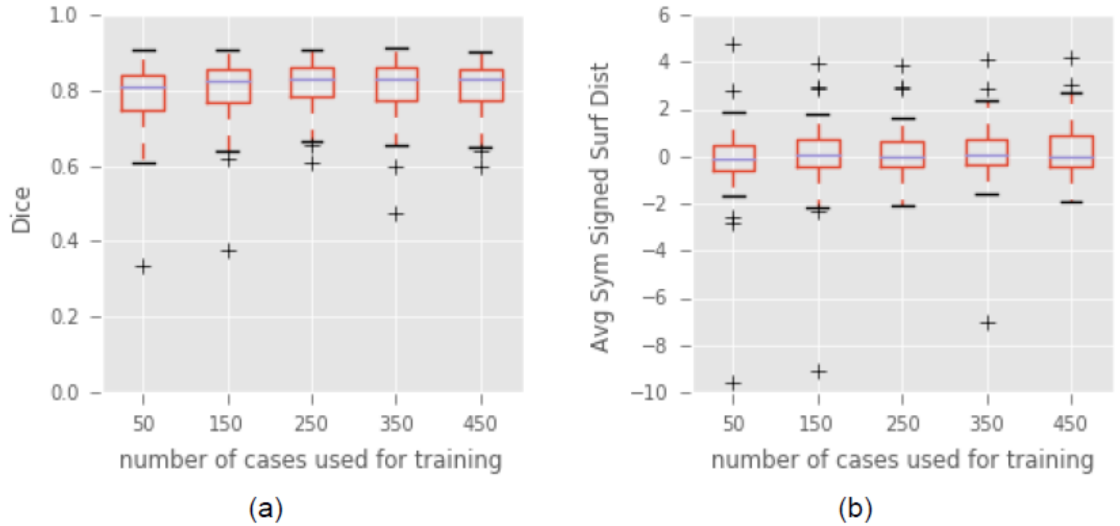


Figure 15: The (a) Dice coefficient and (b) average symmetric signed surface distance were computed on 40 validation cases after training with different numbers of samples.

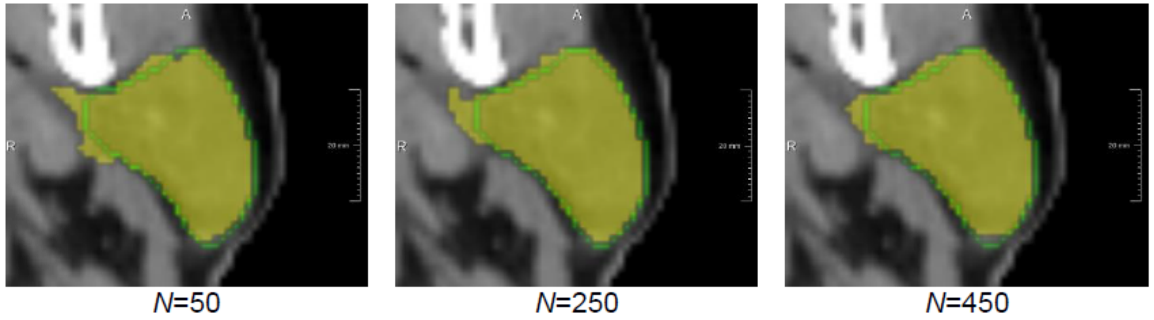


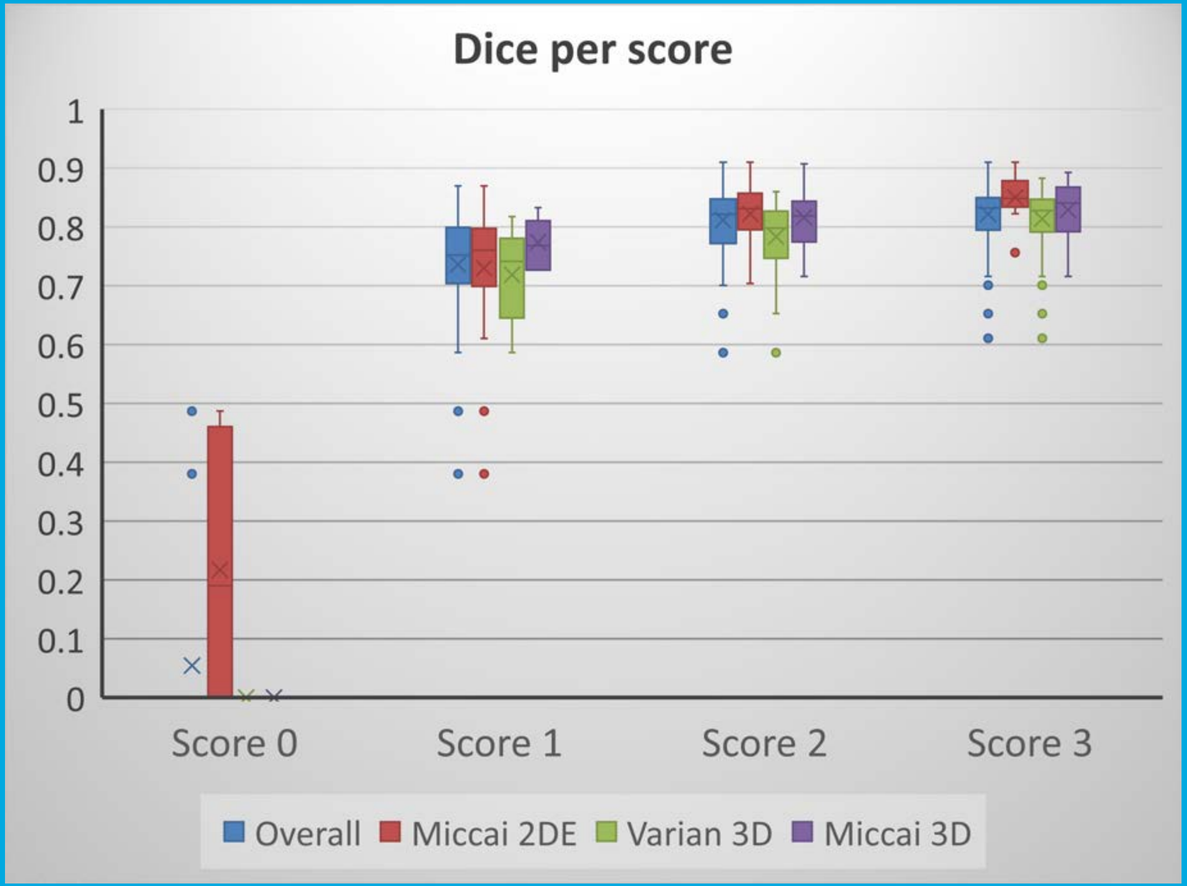
Figure 16: Segmentation result (yellow area) on a validation case and reference (green line) after training on N samples.

Segmentation Lessons II

Clinical Usability – Time Savings

- Clinical rating score
  - 0: Not acceptable, manual (re)drawing of the entire structure required
  - 1: Acceptable, major corrections necessary but with acceptable effort
  - 2: Accepted, only minor corrections required
  - 3: Accepted, no corrections required
- Clinical meaning of DICE
  - DICE can distinguish between acceptable / unacceptable at level approx. 0.75
  - DICE cannot distinguish between discarded and kept
  - DICE cannot distinguish between need for minor or no corrections (ratings 2 and 3)

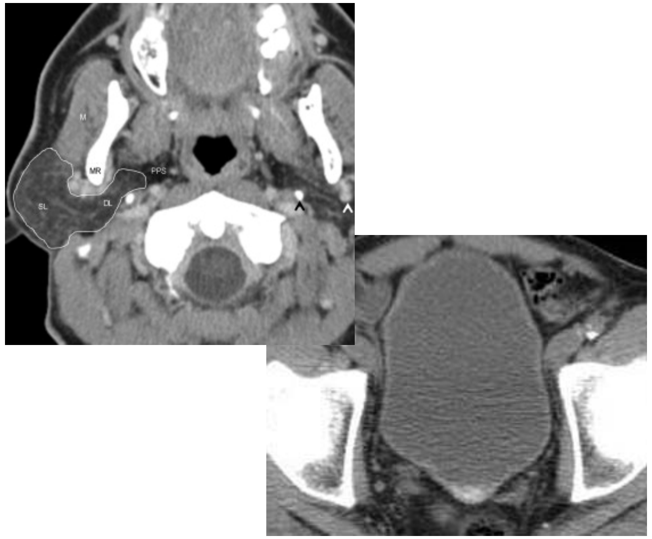
$$Dice = \frac{2 \cdot |mask \cap prediction|}{|mask| + |prediction|}$$



Segmentation Problem Classes

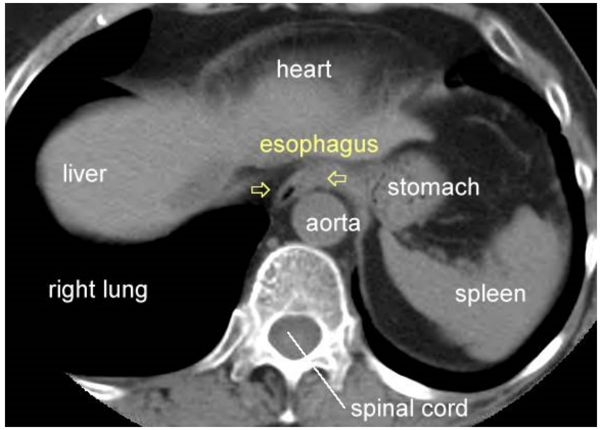
Class 1

- Visible on CT, common agreement on shape
- Parotids, Bladder



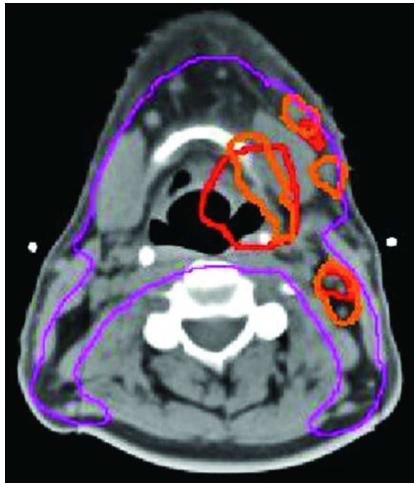
Class 2

- Ground truth needs multiple clinicians and/or modalities
- Rectum, Esophagus, Uterus, Prostate



Class 3

- Ground truth depends on guideline, disease, physician
- nodal targets, oral cavity



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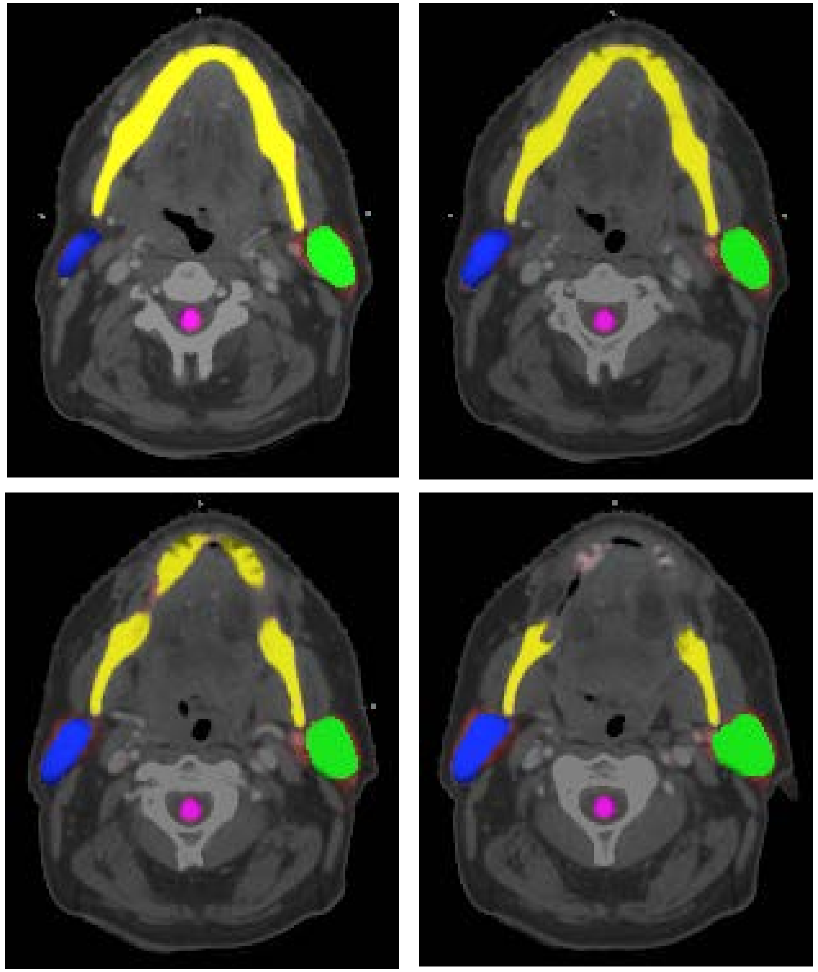
Multi-Aspect Head-and-Neck Results

- Multi-aspect model that contours at once:
  - parotids (left and right)
    - 0.83 median Dice
  - mandible
    - 0.90 median Dice
  - spinal cord
    - 0.82 median Dice
- 90/10/35 training/validation/test patients
  - RapidPlan data
- No postprocessing



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Bladder Results

- Bladder model
  - 0.94 / 0.96 mean / median Dice
- 140/20/38 training/validation/test patients
- No postprocessing

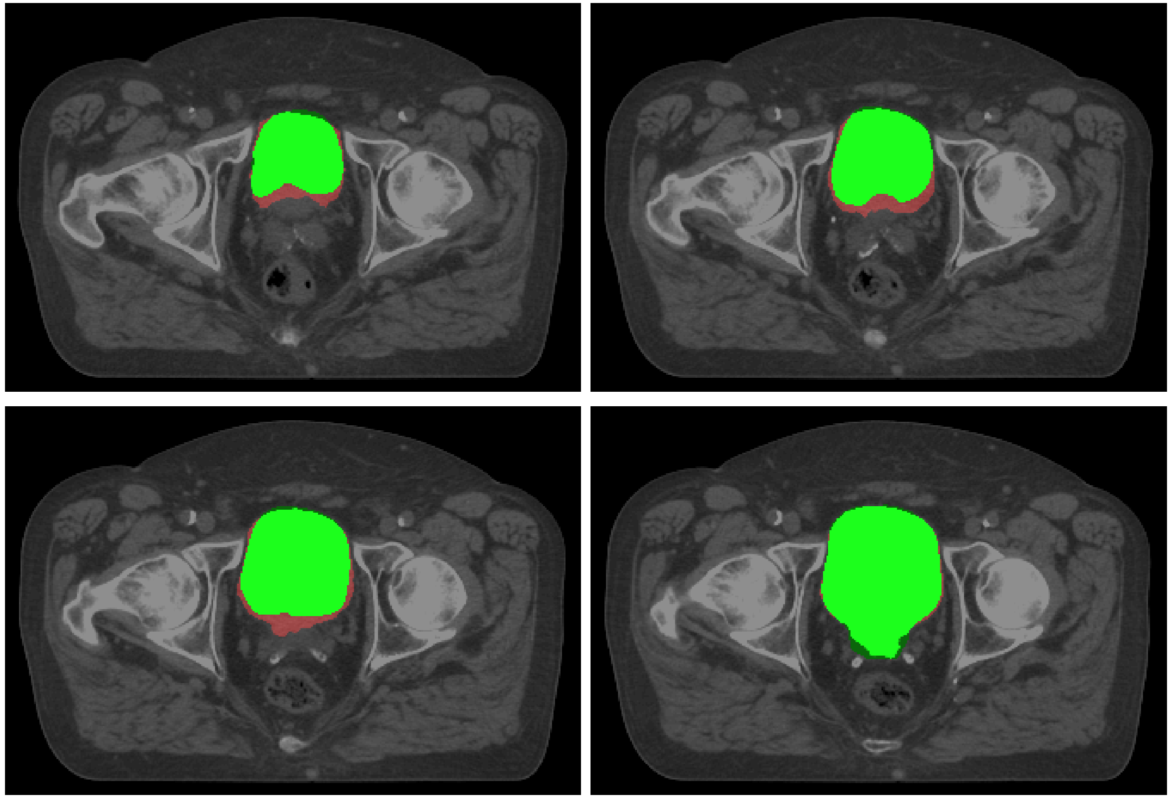

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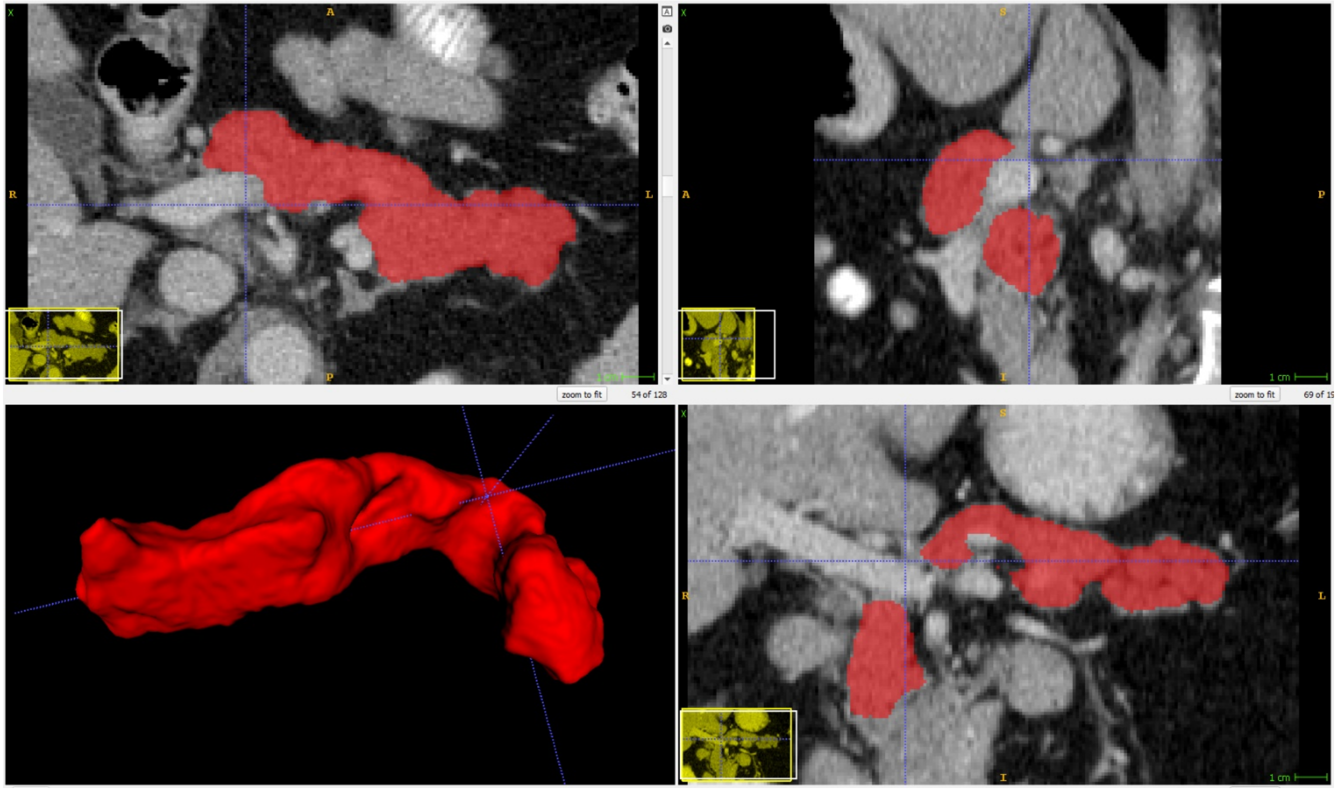
Image Segmentation: Pancreas Simulation-CT

Validation Study (N=10)

Test Case	Mean 3D Surface Distance [mm]	Dice
1	1.1	0.89
2	1.7	0.81
3	1.1	0.89
4	1.1	0.88
5	1.4	0.82
6	1.1	0.86
7	1.4	0.82
8	1.2	0.87
9	1.5	0.84
10	1.2	0.86
Overall	**1.3 ± 0.2 mm** min: 1.1 mm max: 1.7 mm	**0.85 ± 0.03** min: 0.81 max: 0.89



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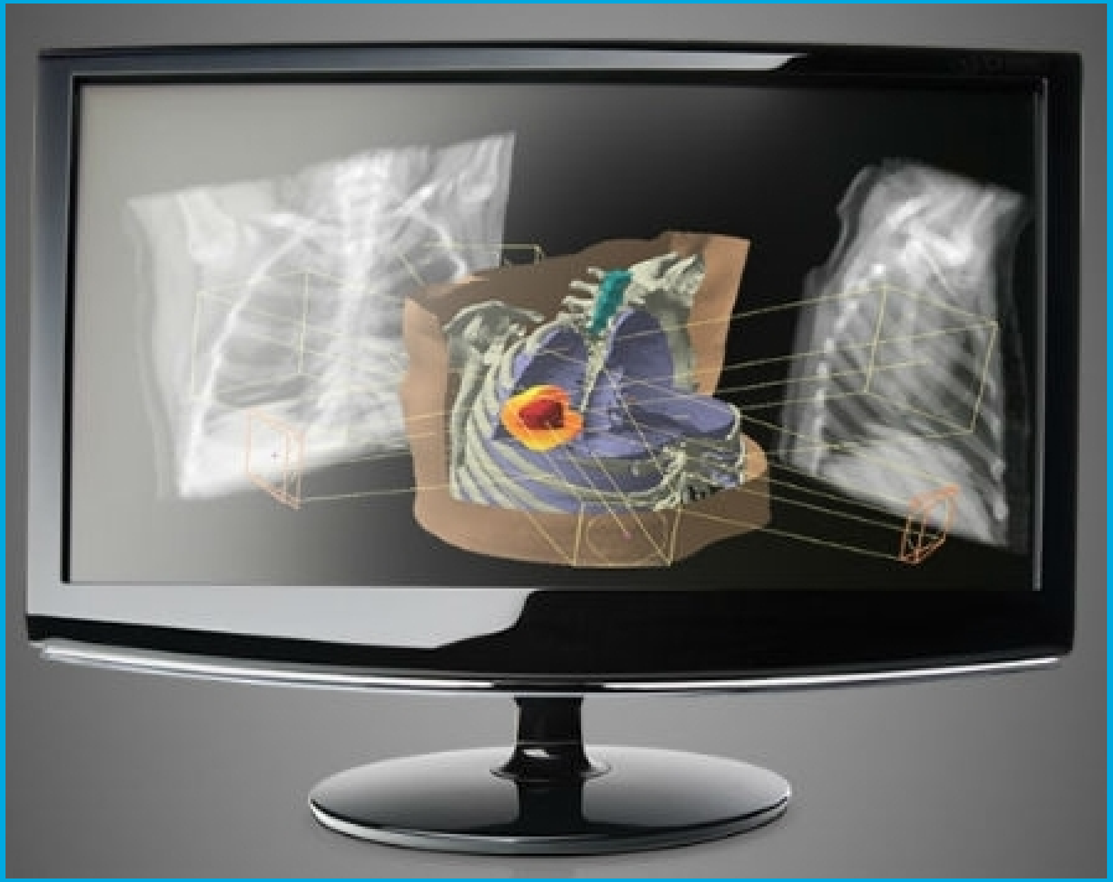
Automated Treatment Planning

Needs and Opportunities

- Market: LMIC have limited access to skilled treatment planners and limiting their access to radiation therapy equipment
- Customer: Developed markets want standardization, high quality and efficiency (time and resource intense)
- Varian: Radiation therapy industry will move quickly on AI for automation
- Opportunities
  - AI can automate many of these processes
  - Training data can be made available
  - Computing power is available and affordable



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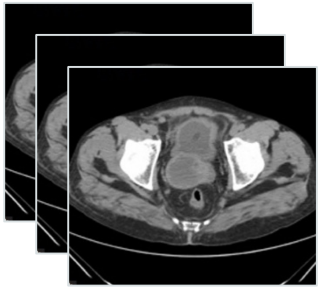
Automating Treatment Planning

- Manual Process
- Automated Process

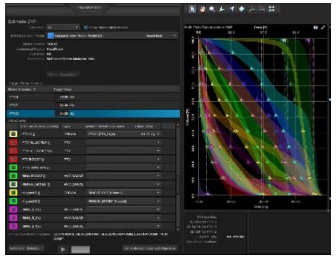
Today’s Manual Workflow

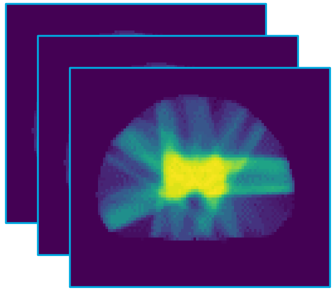
Rx / Images → Segment → Set Beam Geometry → Predict 3D Dose → Generate Plan → Review → Schedule Patient



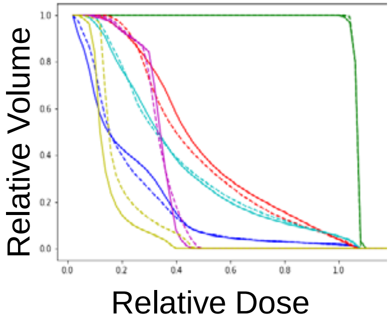
DICOM CT Image

DICOM RT Structure Set





DICOM RT Dose



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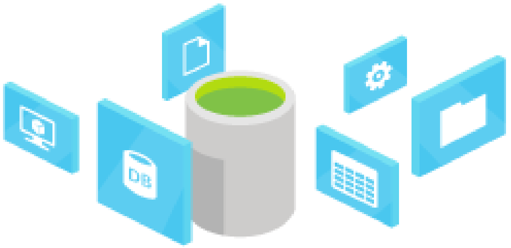
DICOM RT Plan

Varian’s machine learning (ML) environment

Work in Progress

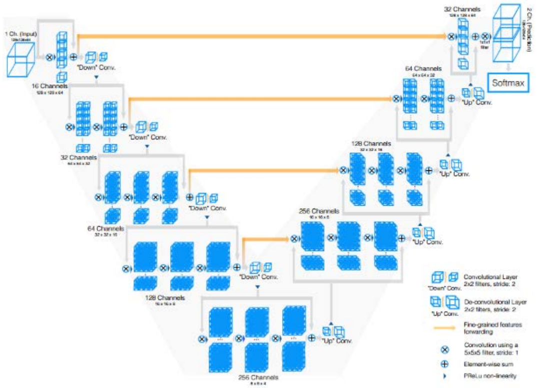
- Develop a terabyte-scale storage solution for semi-structured clinical data – data consortium
- Establish a ML environment for use by Varian and consortium partners – federated data, distributed learning
- Develop expertise in AI model deployment to guide technical and business decisions

Data

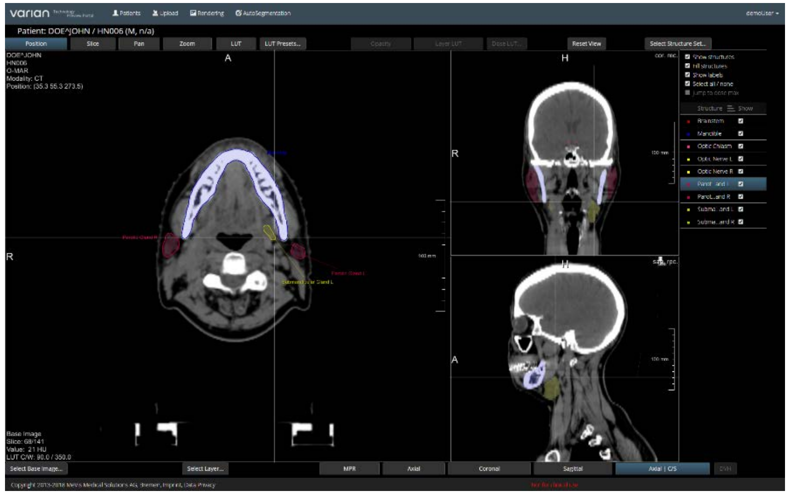


Data Lake

Models



Deployment



Thank You

Conclusions

There is a bright future ahead

- Very positive but early evidence that deep learning based segmentation algorithms are outperforming existing ones
- Model responses are fast
- We see various areas in our domain where AI and deep learning can significantly help solving existing shortcomings and increase efficiency
- Varian Medical Systems is increasing it’s activities in this field across the development process
- First knowledge based product already on the market
- Deep learning based products are already in development

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