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Deep Learning & Beyond:

Medical image recognition, segmentation and parsing

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Principal Key Expert of Image Analysis
Siemens Healthineers, Medical Imaging Technologies

A global leader in healthcare

SIEMENS Healthineers

~210,000
patient touch points every hour

>90%
of global top 100 providers partner with us

>46,000
highly skilled employees

Access to care for
~1.1bn people
in developing countries

75
developed and emerging countries with direct presence

12,500+
Patents IP base

~600,000
Installed base

>70%
of critical clinical decisions are influenced by what we provide

Innovations is the main driver

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MRI 1980

MRI today

Data courtesy of CUBRIC, UK
Cinematic Rendering: Research use only. Not for clinical use.

Brain anatomy – MR 7T
Cinematic rendering

Data courtesy of Max Planck Institute Leipzig, Germany
Cinematic Rendering: Research use only. Not for clinical use.

Computed Tomography at Siemens Healthineers
40+ years of Innovation

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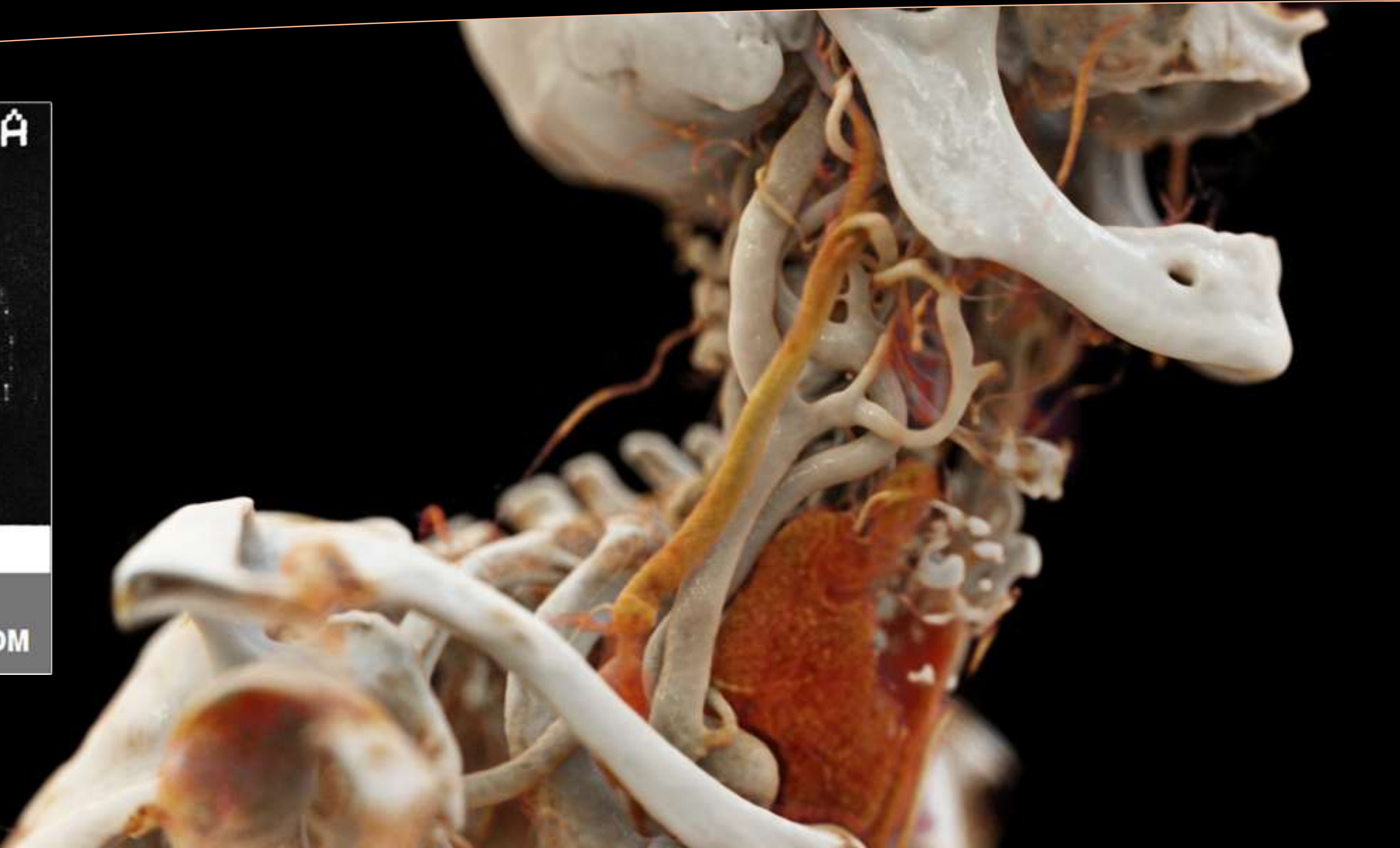


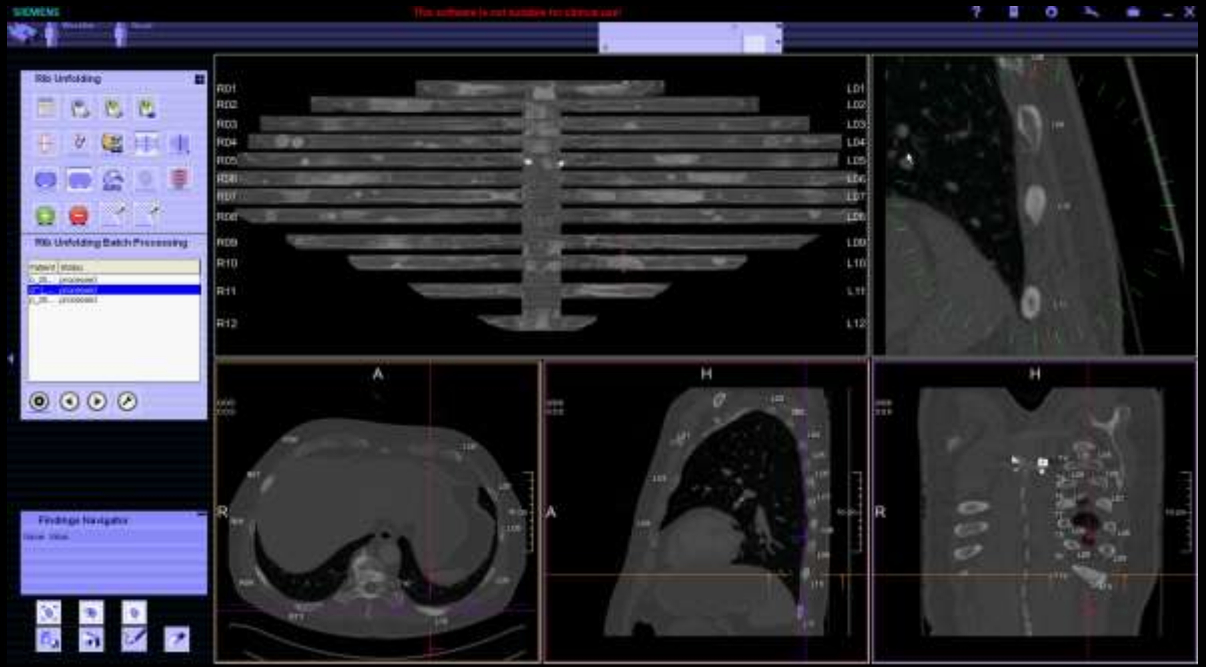
Data courtesy of Israelitisches Krankenhaus,
Hamburg, Germany
Cinematic Rendering: Research use only.
Not for clinical use

Abdominal aneurysm and aortic stents
Cinematic Rendering

Data used to create these images were acquired at the UniversitätsSpital Zürich, Switzerland.

Cinematic Rendering: Research use only. Not for clinical use

Rib Unfolding



- Ringl H et al. The ribs unfolded - a CT visualization algorithm for fast detection of rib fractures: effect on sensitivity and specificity in trauma patients. Eur Radiol 2015; 25:1865-74
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed

Transcatheter Aortic Valve Implantation

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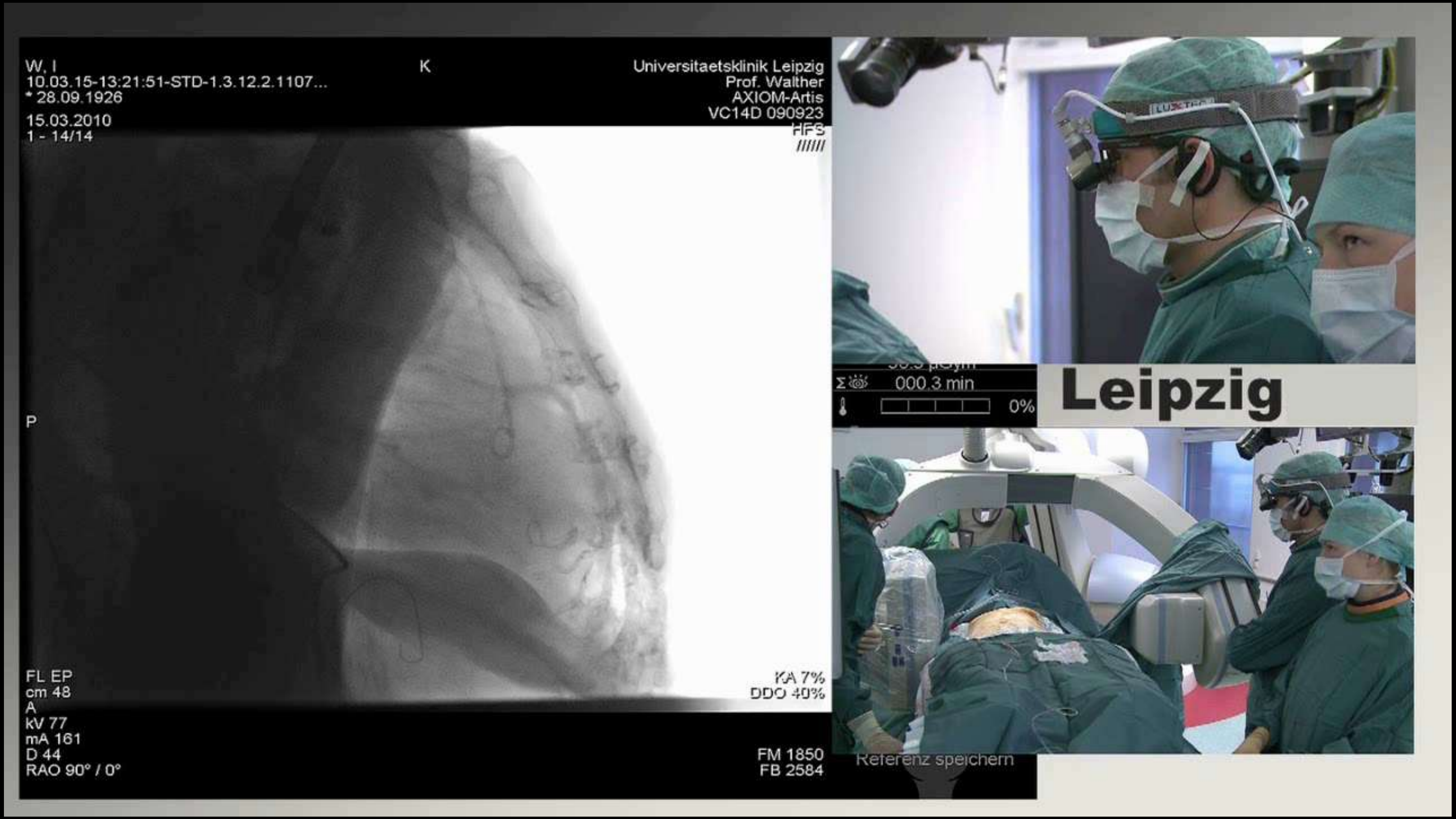


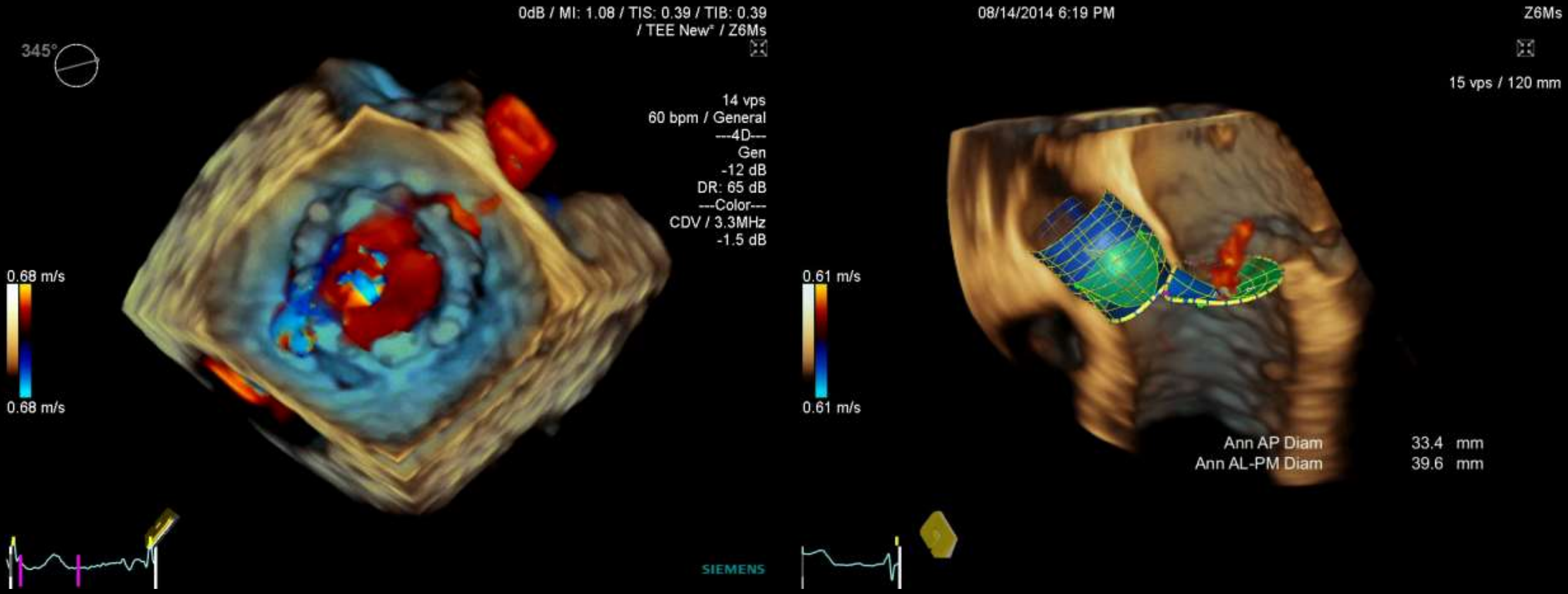
•The C-arm acquires 3D images by rotating around the patient

•The images are automatically reconstructed, segmented, and landmarks and the "perpendicularity ring" are detected

- Y. Zheng et al, Automatic Aorta Segmentation and Valve Landmark Detection in C-Arm CT for Transcatheter Valve Implantation, IEEE TMI 2013
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Courtesy of Leipzig Heart Center

eSie Valves



True Volume TEE and Real-Time 3D Doppler
Para-valvular Leakage

Holy grail: Medical image parsing

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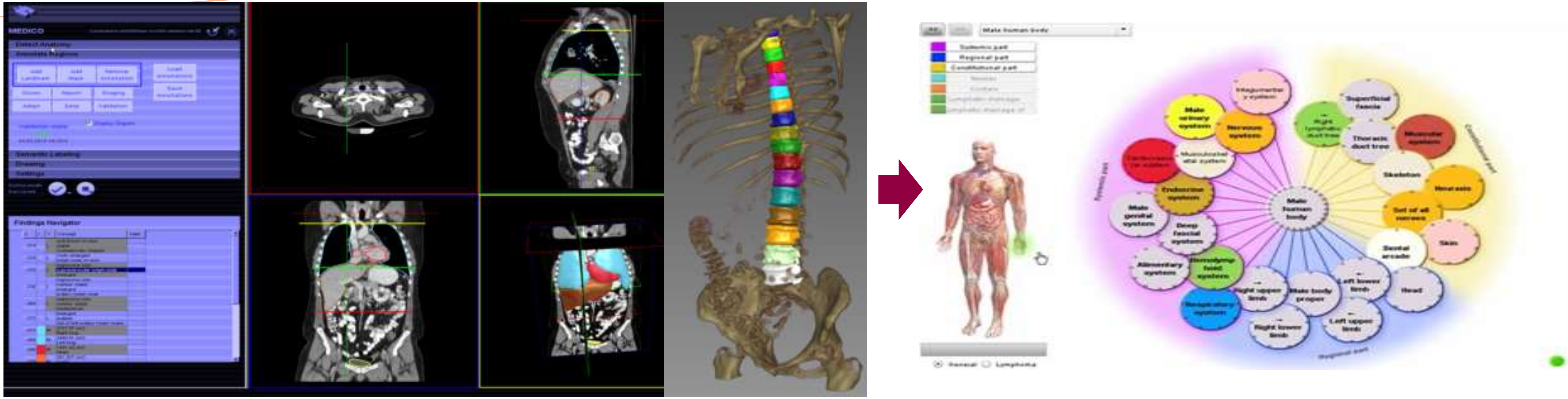

Medical image parsing

- Assigning semantic labels to pixels or voxels
- Unifying detection, segmentation, and parsing

Technology benefits

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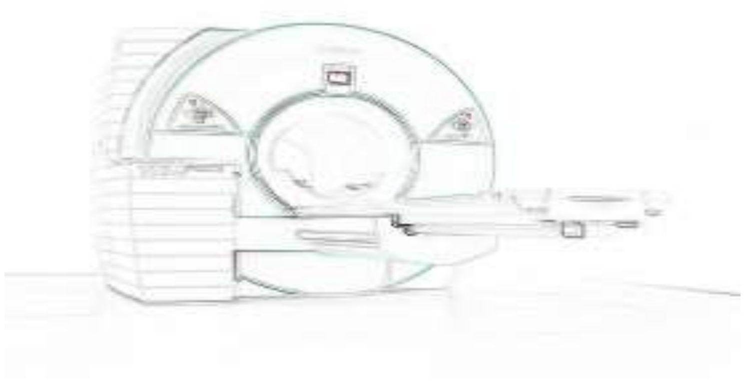
Scanner



- Automated
- Personalized
- Consistent
- Fast
- Less radiation

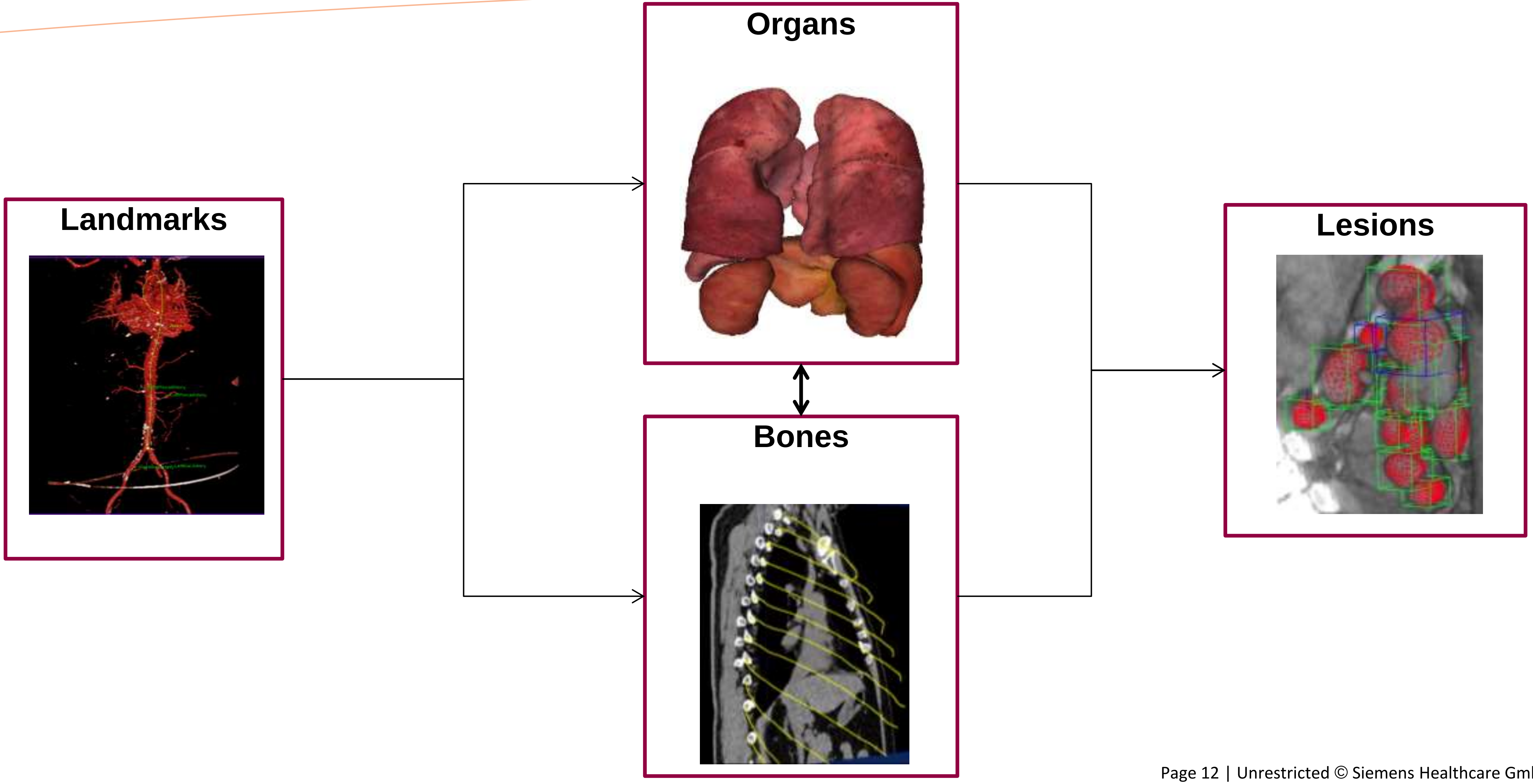
Reading

- Structured reading
- Streamlined workflow
- Semantic reporting

Quantification

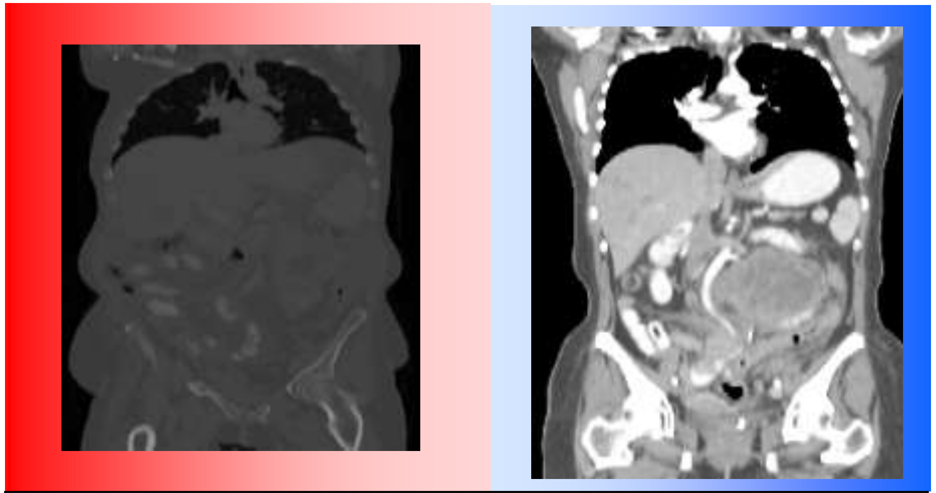
- Adv. measurements
- CAD
- Surgery planning
- Therapy prediction & monitoring

Major parsing objects



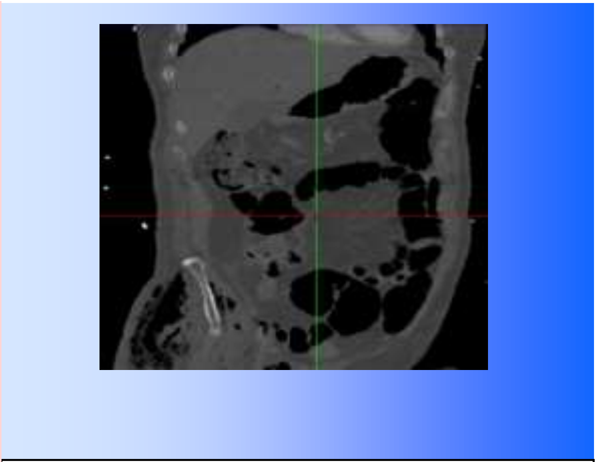
Challenges

Image and shape variations



Contrast

Context



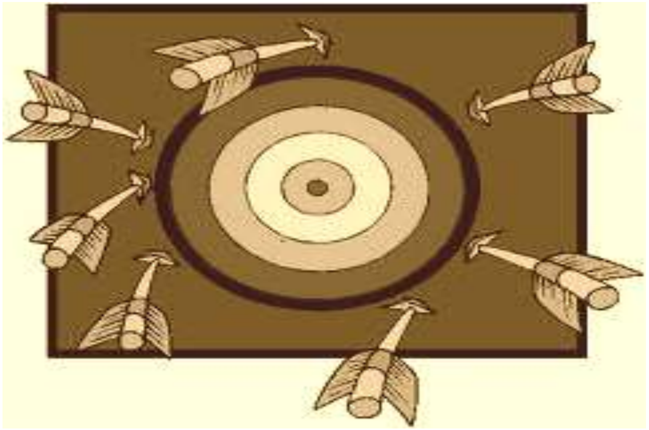
Pathologies

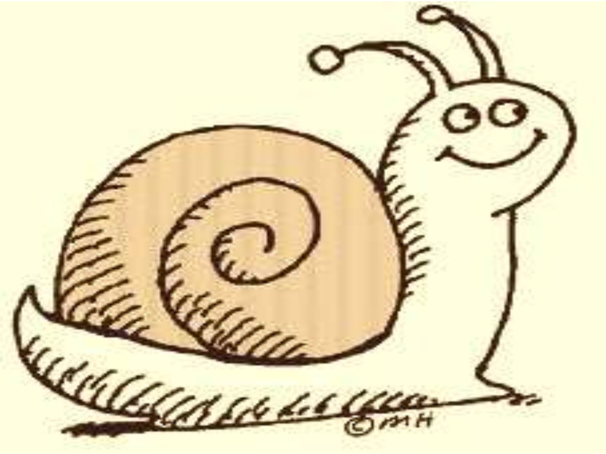
- Deformed, missing, misleading context

Body Portions

- Narrow FOV , Severe Occlusion

Additional challenges





Robustness:
No outlier

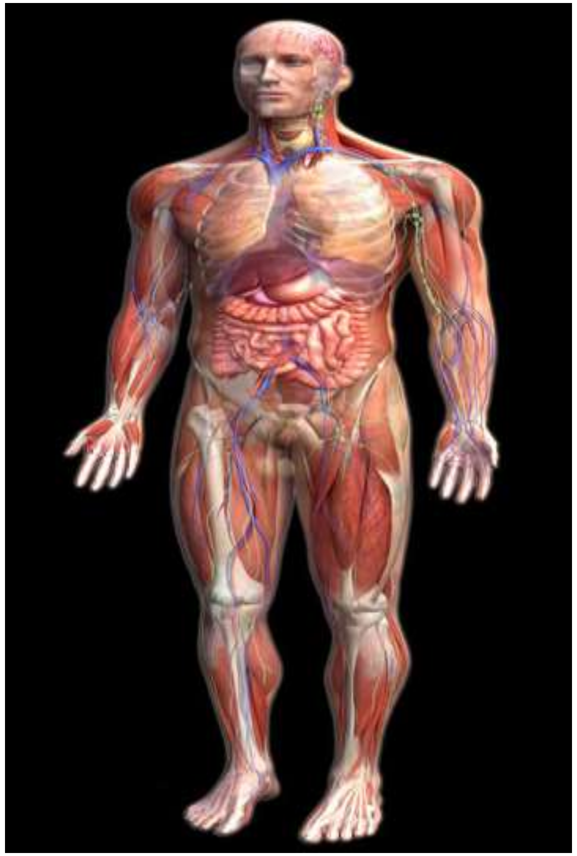
Accuracy:
Within inter-user variability

Speed:
Less than a few seconds

Opportunities

Large Amount of Datasets

+



Anatomical Context

=

Machine Learning

+

Knowledge

Machine learning + Knowledge

Machine learning

- Supervised learning
  - Deep neural network
  - SVM, boosting, etc.
- Unsupervised learning
- (Deep) Reinforcement learning

+

Knowledge

- Human anatomy
- Scanner protocol
- Prior constraints
- Math. theorems
- Physics laws
- Logic

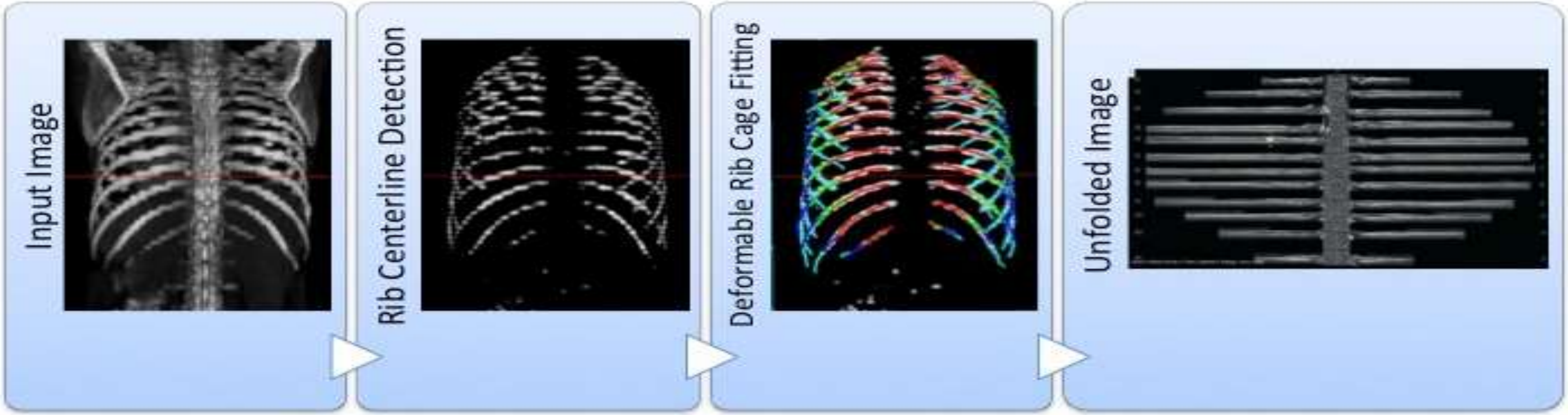
syngo.via CT bone reading

Oscar of invention

- Visualization of all ribs in one plane
- Automated numbering
- Reduces reading time
- Improves diagnostic sensitivity

- Patent US8989471 B2, Method and system for automatic rib centerline extraction using learning based deformable template matching.
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

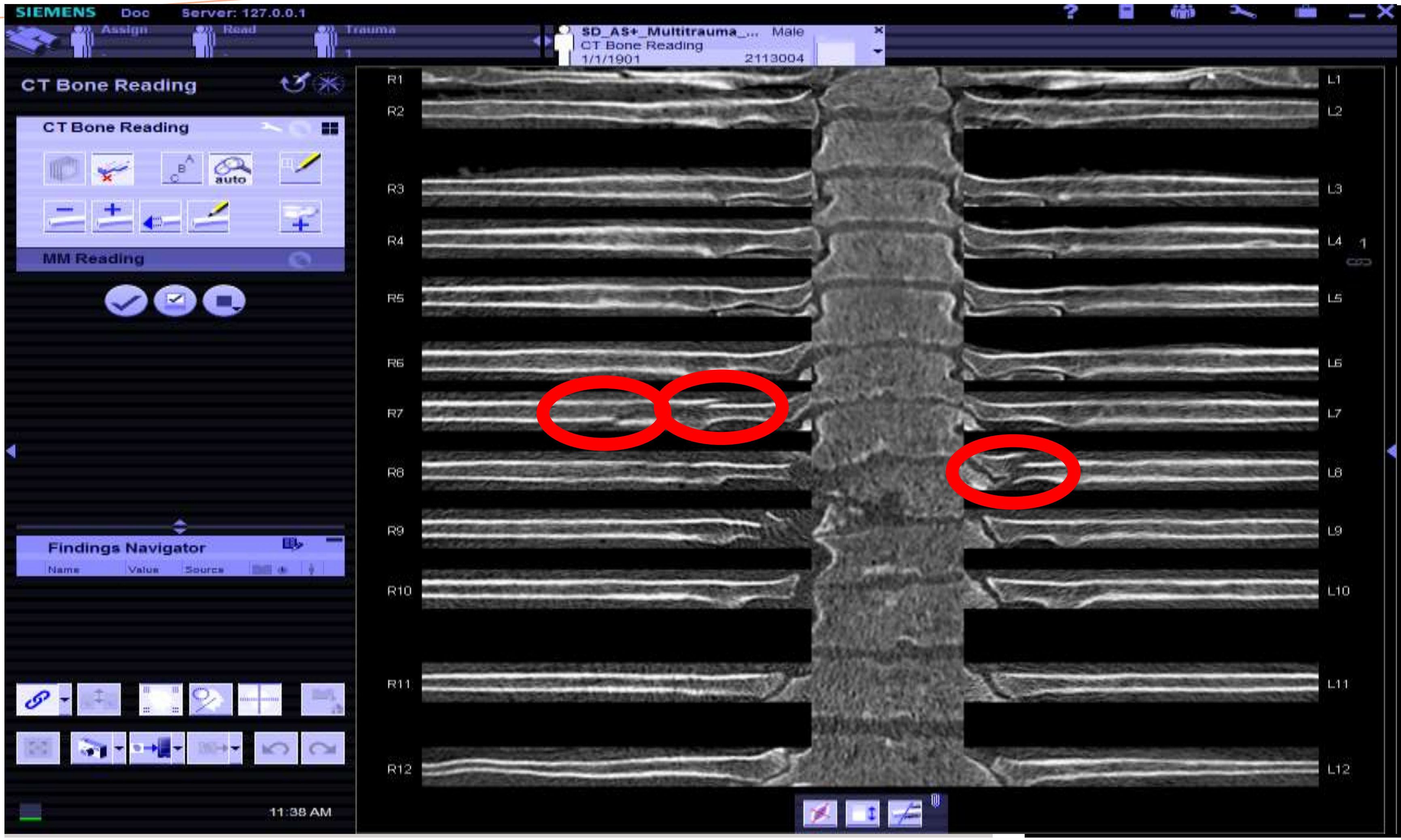
ML + Rib cage model fitting



- Wu et al, “A learning based deformable template matching method for automatic rib centerline extraction and labeling in CT images,” CVPR 2012.
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

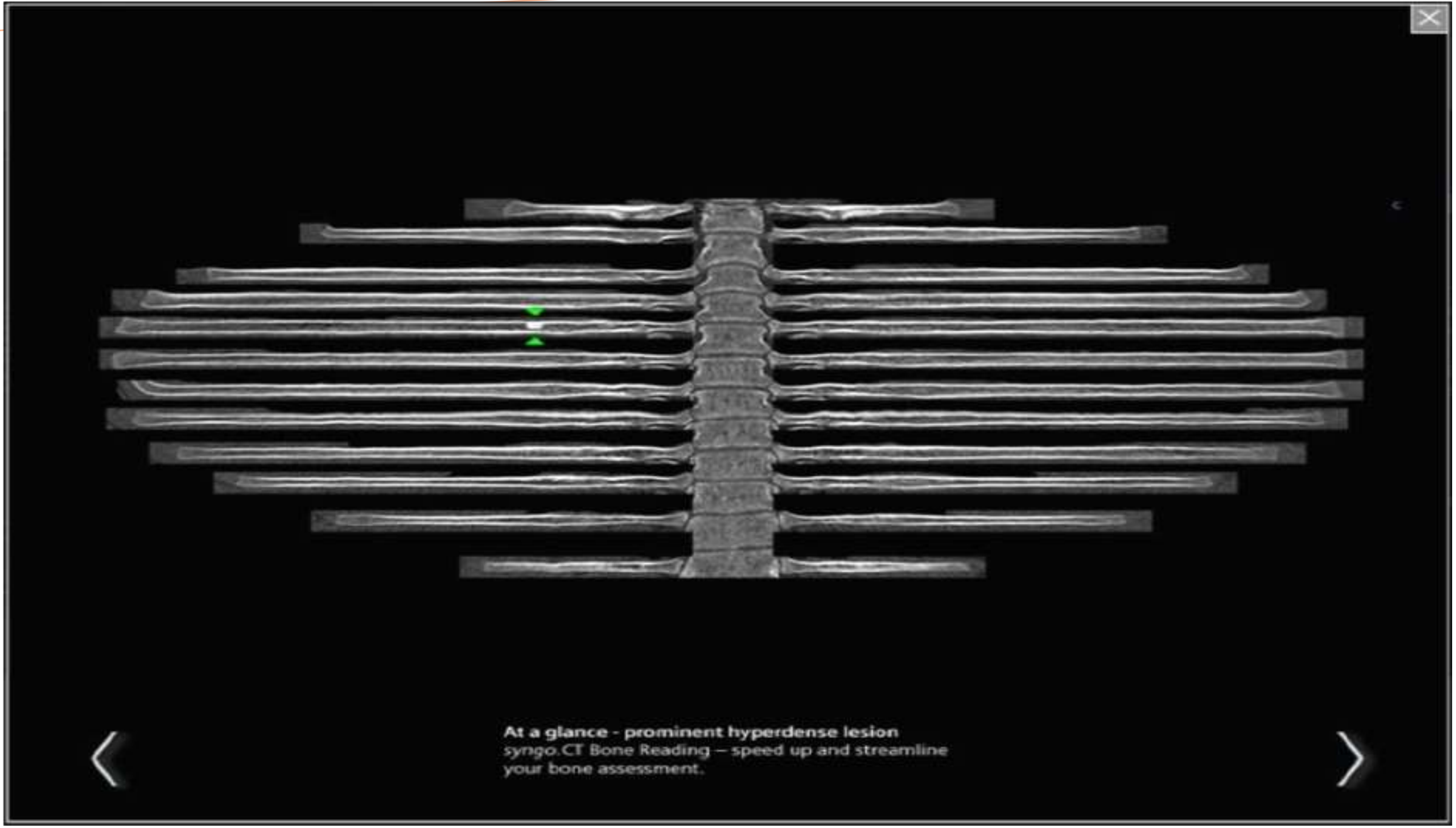
 |

Fractures



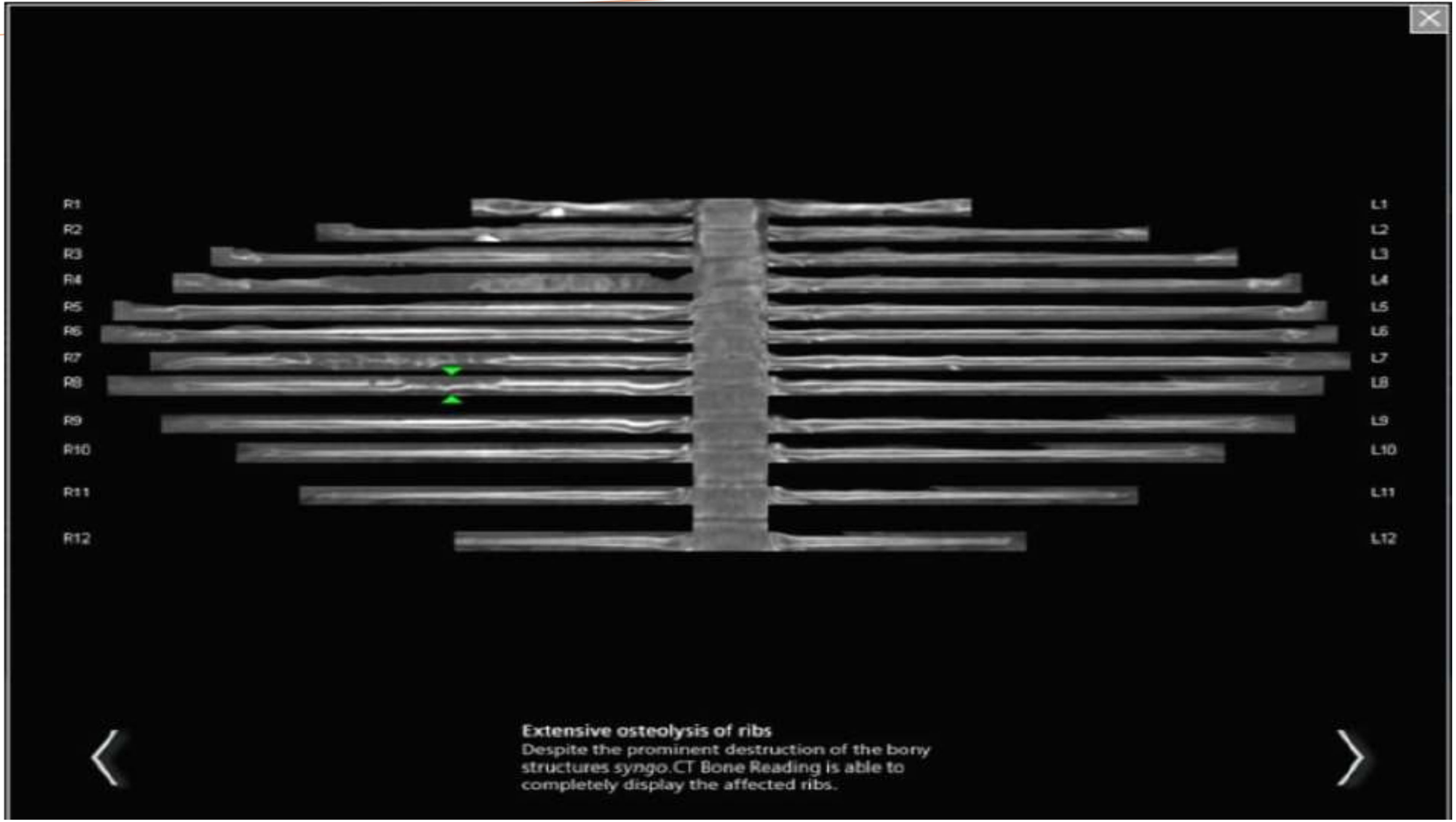
This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed

Hyperdense lesion



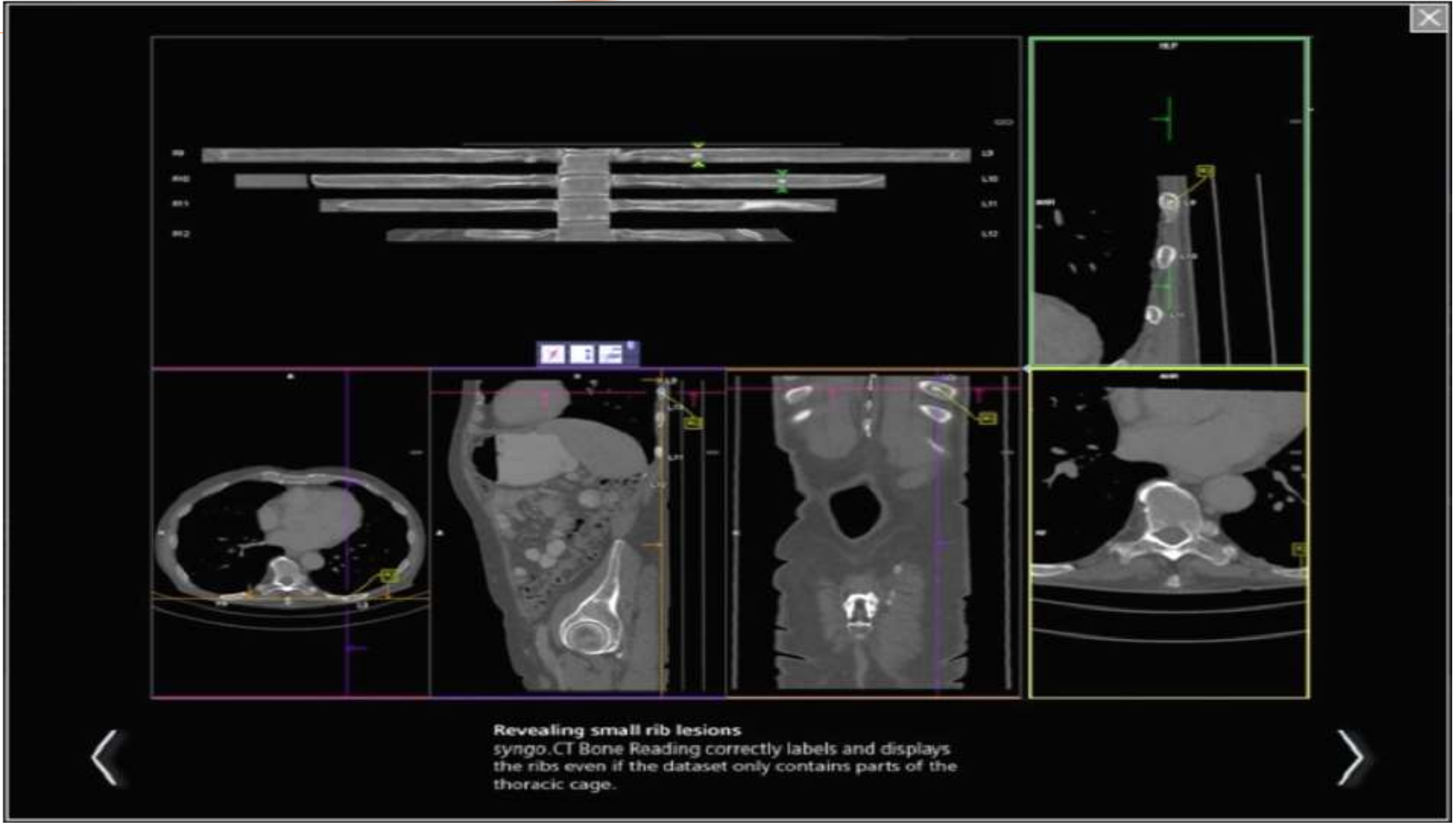
This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed

Osteolysis



This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed

Incomplete rib cage



This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed

Skeleton unfolding

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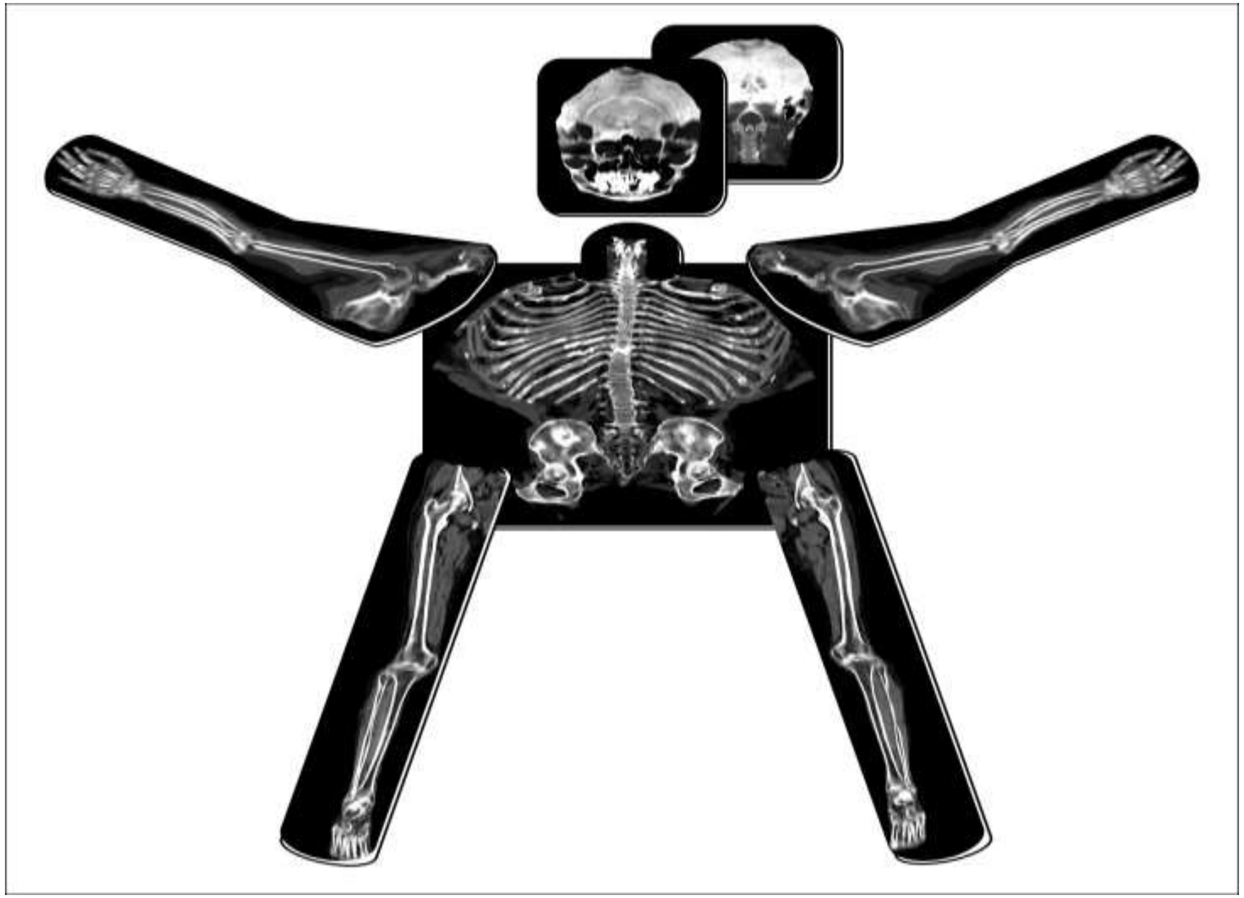


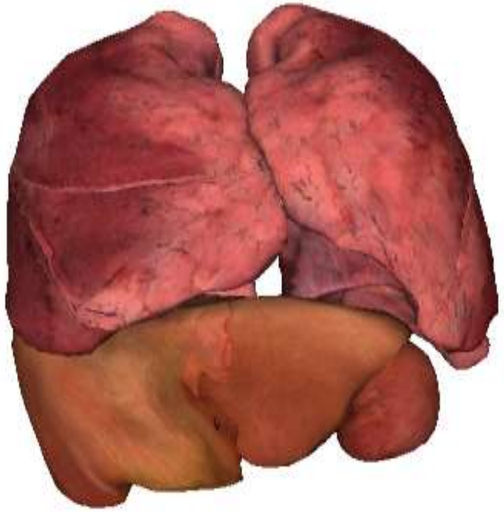
- Patent US9558568 B2: Visualization method for a human skeleton from a medical scan
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Context

Unitary / Local Context

Holistic / Global Context

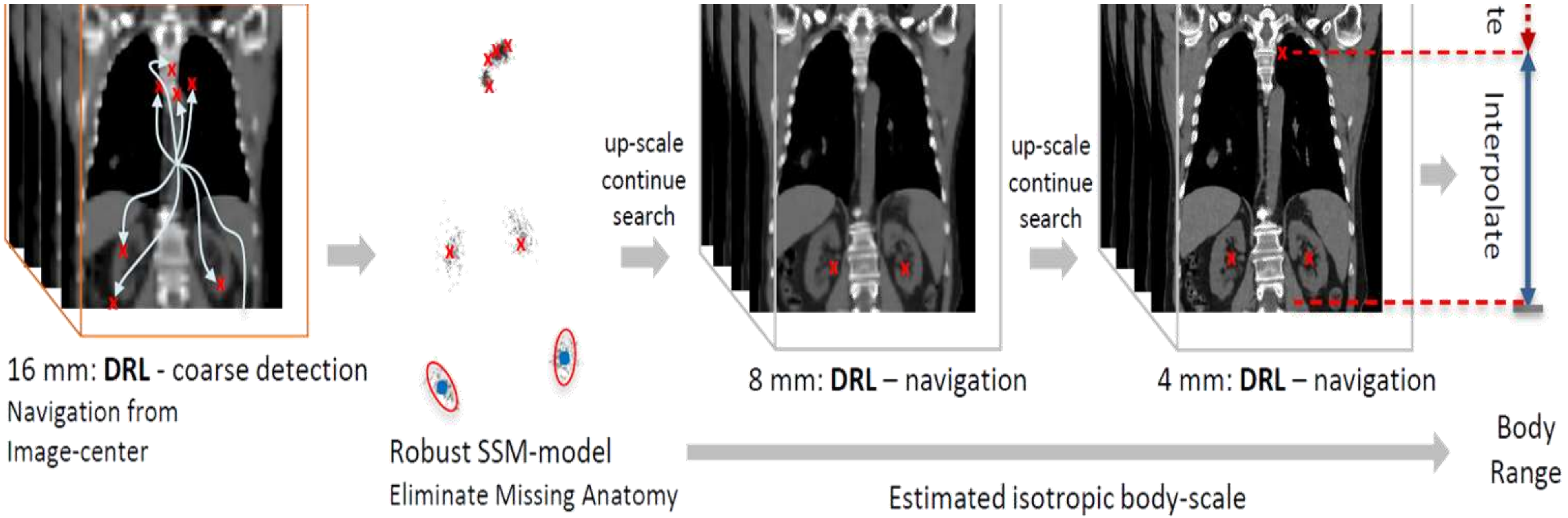
Rapid multi-organ segmentation



- **Accuracy: ~ inter-user variability**
- **Running time: 1-2 seconds**

- US Patent 7949173, “Method and system for regression-based object detection in medical Images”
- Lay et al, “Rapid multi-organ segmentation using context integration and discriminative models,” IPMI 2013.
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Multi-scale deep RL for 3D body markers



Validated on **2305 CT volumes**

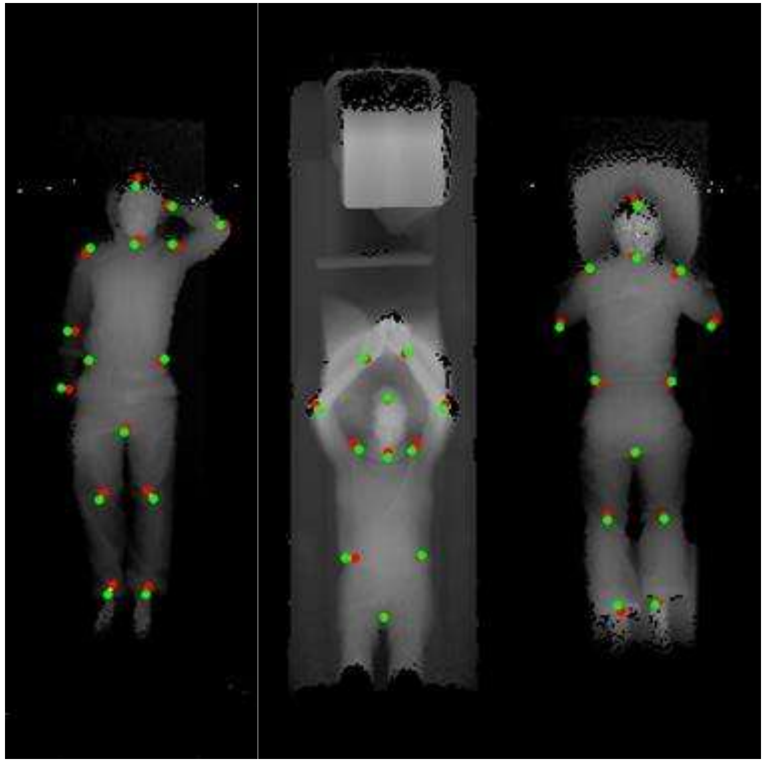
Focus on robustness: **No failures!**

Real time speed: 0.8s (8 body markers)

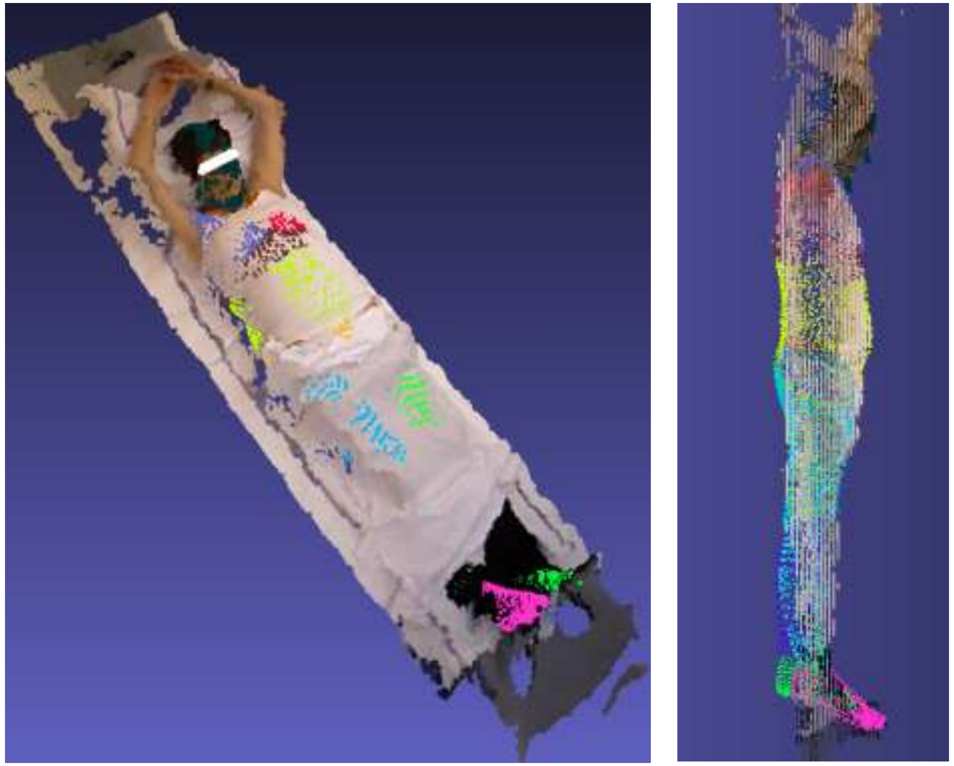
Comparison with other Deep Learning & SADNN

- Ghesu et al., Robust Multi-Scale Anatomical Landmark Detection in Incomplete 3D-CT Data, Medical Image Analysis, MICCAI 2017
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

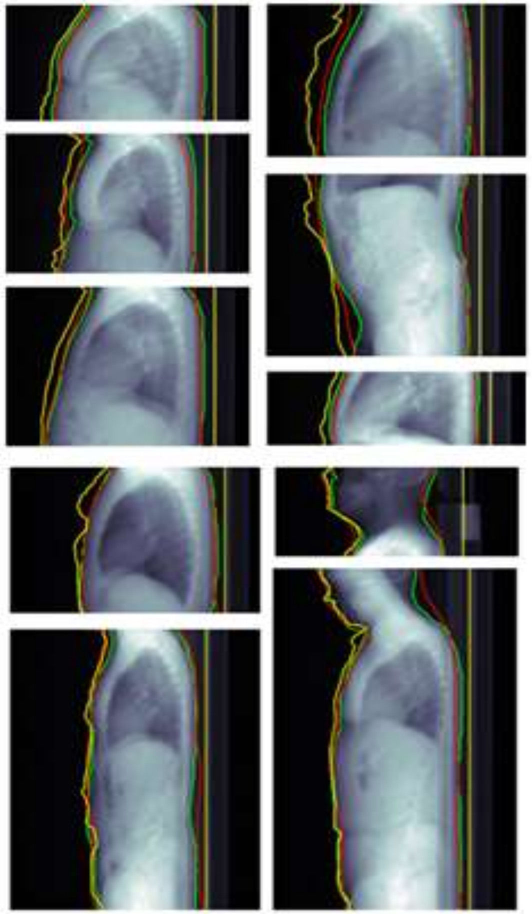
DARWIN – AI-based patient specific avatar modeling



Pose & bodymarkers



Mesh representation



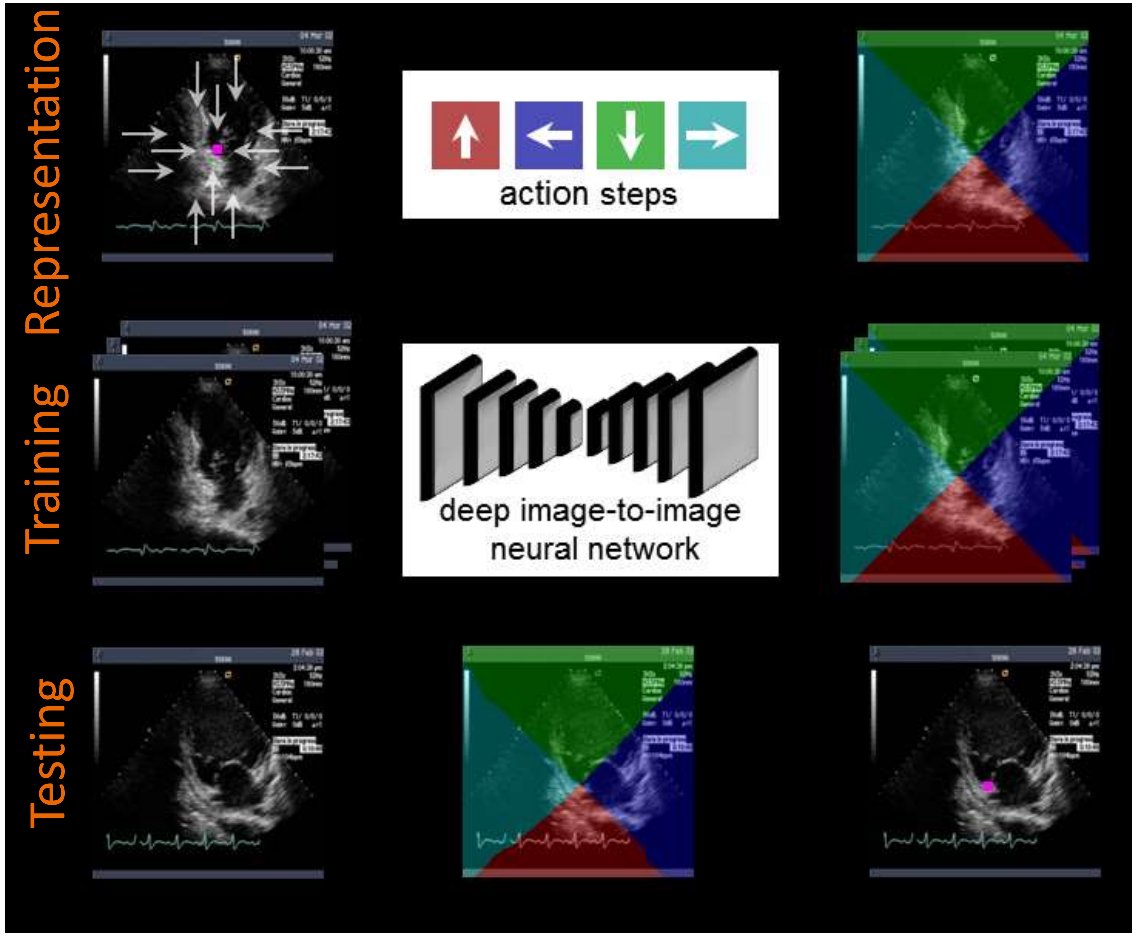
Validation through CT imaging

- Singh, et al. DARWIN: Deformable Patient Avatar Representation With Deep Image Network, MICCAI 2017.
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Landmark detection using DI2IN + supervised action map

- Novel representation -- supervised action map
- Deep image2image network (DI2IN)

		PBT		DRL		I2I		SAC	
		lmk1	lmk2	lmk1	lmk2	lmk1	lmk2	lmk1	lmk2
CA	mean	10.45	13.85	7.69	10.02	6.73	9.02	**6.31**	**8.01**
	50%	5.74	8.11	5.43	7.63	5.00	6.40	**4.35**	**5.88**
	80%	11.11	16.18	9.33	13.73	8.54	11.40	**7.54**	**10.83**
OB	mean	59.23	130.66	29.99	32.45	30.07	21.97	**14.94**	**16.76**
	50%	35.31	139.49	11.69	13.17	5.39	6.08	**4.85**	**5.91**
	80%	109.84	193.64	43.98	45.76	13.34	15.54	**11.76**	**13.67**

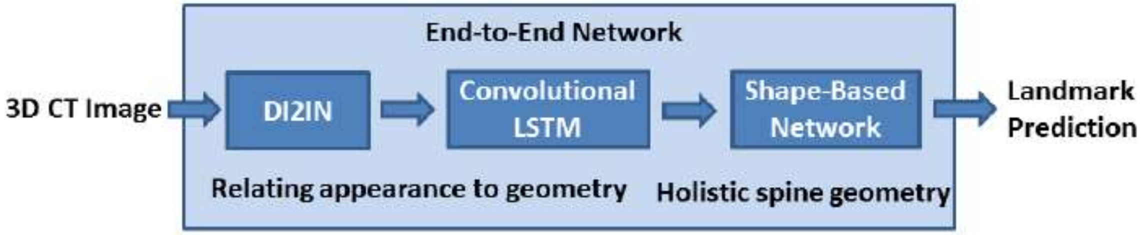


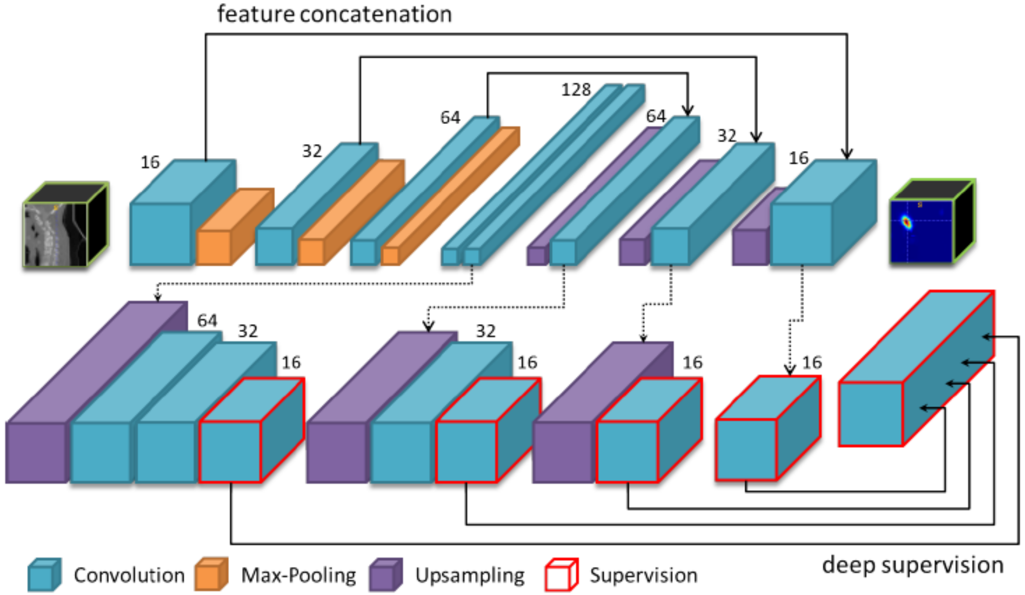
- Xu et al., Supervised Action Classifier: Approaching Landmark Detection as Image Partitioning, MICCAI 2017.
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Vertebral landmark detection using deep image2image recurrent network

- DL + shape constraints
- Reducing failure rate by 14% compared to best method on public benchmarking data set

Region	Method	Set 1			Set 2		
		Mean	Std	Id.Rates	Mean	Std	Id.Rates
All	Glocker *et al.* [2]	12.4	11.2	70%	13.2	17.8	74%
	Suzani *et al* [4]	18.2	11.4	-	-	-	-
	Chen *et al.* [3]	-	-	-	8.8	13.0	84%
	Our method	10.6	**8.7**	78%	8.7	8.5	85%
	Our method +1000	**9.0**	8.8	**83%**	**6.9**	**7.6**	**89%**



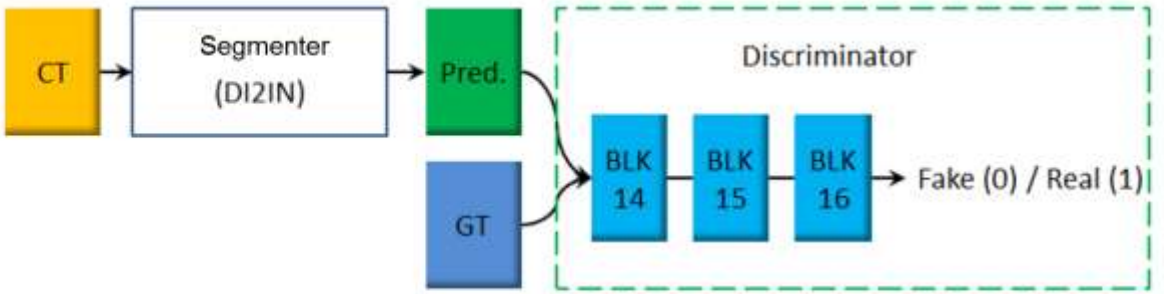


- Yang et al., Deep Image-to-Image Recurrent Network with Shape Basis Learning for Automatic Vertebra Labeling in Large-Scale 3D CT Volumes, MICCAI 2017
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Adversarial Image2Image Network for Organ Contouring

Adversarial Image-to-Image Network

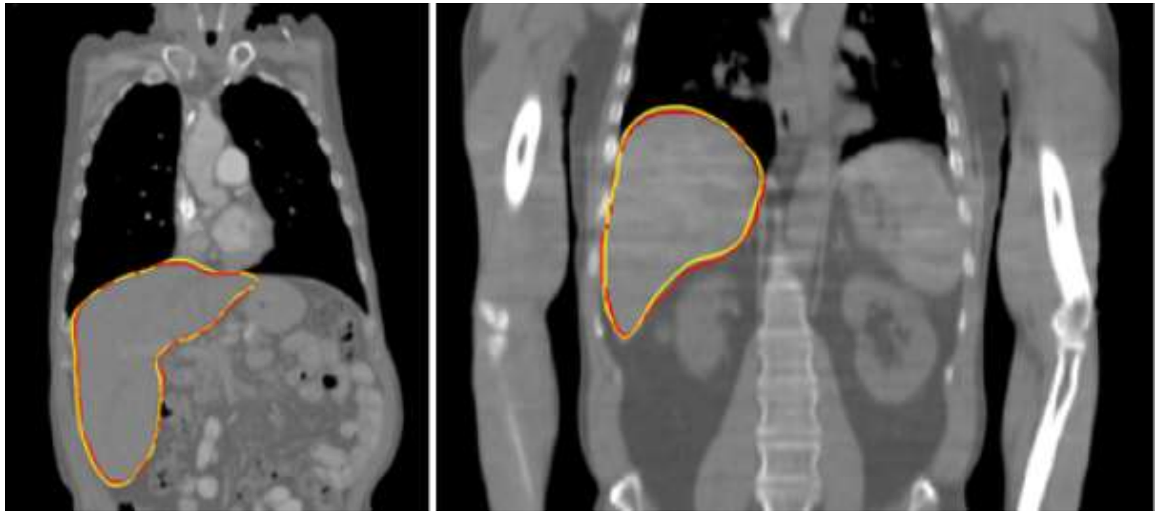
- Using segmentation (DI2IN) and discriminative models to improve segmentation performance



Liver segmentation

- 34% error reduction when using 1000 CT data sets

Method	ASD (mm)			
	Mean	Std	Max	Median
Ling *et al.* (400) [5]	2.95	5.07	37.45	2.01
DI2IN (400)	2.38	1.31	10.35	2.0
DI2IN-AN (400)	2.09	0.94	7.94	1.88
DI2IN (1000)	2.15	0.81	6.51	1.95
DI2IN-AN (1000)	**1.95**	0.75	**6.48**	**1.81**



Data courtesy of Universitätsspital Basel

- Yang et al., Automatic Liver Segmentation Using an Adversarial Image-to-Image Network, MICCAI 2017
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

Robust multi-modality image fusion – within seconds
Artificial agent trained using DRL

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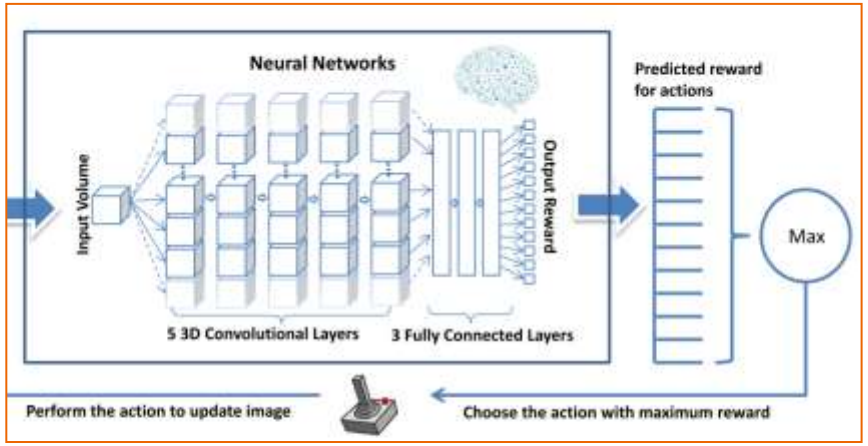
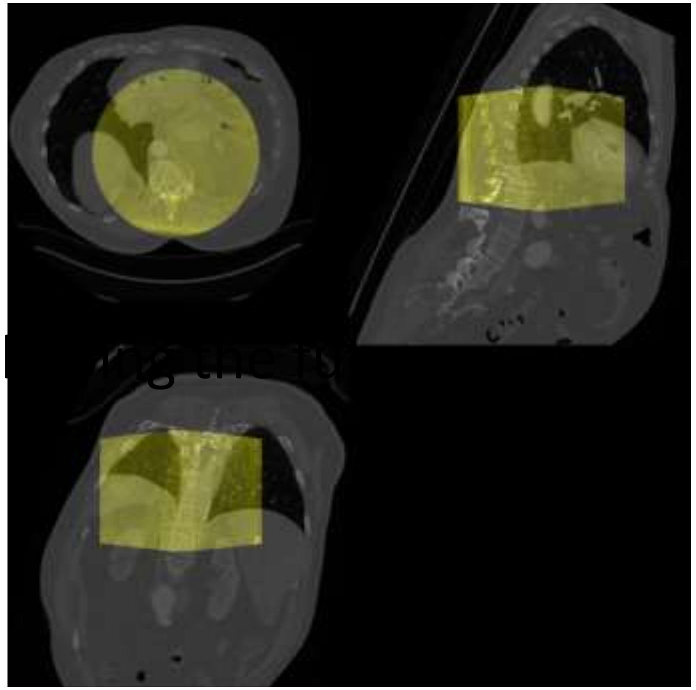
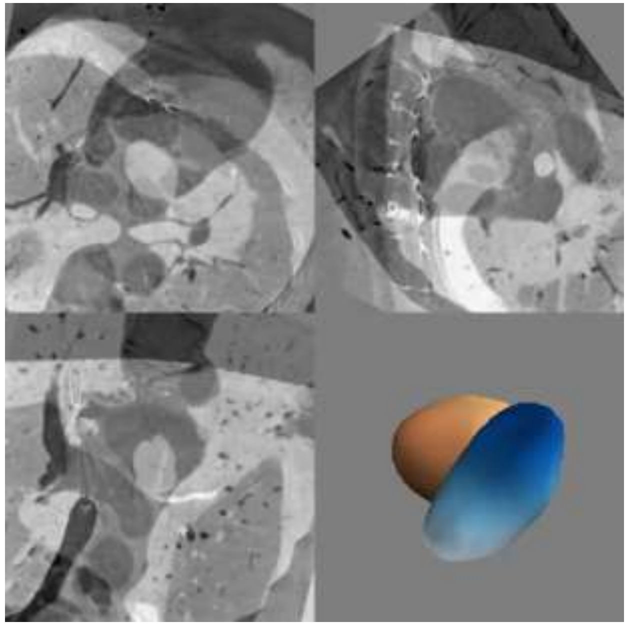
- Applies to 3D/3D rigid/deformable registration, 2D/3D (multi-agents)
- Trained on 5M training pairs





CT/DynaCT Spine

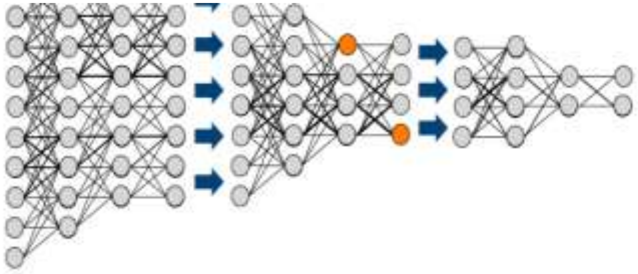


CT/DynaCT Heart

- Liao et al., An Artificial Agent for Robust Image Registration, AAAI 2017.
- This feature is based on research, and is not commercially available. Due to regulatory reasons its future availability cannot be guaranteed.

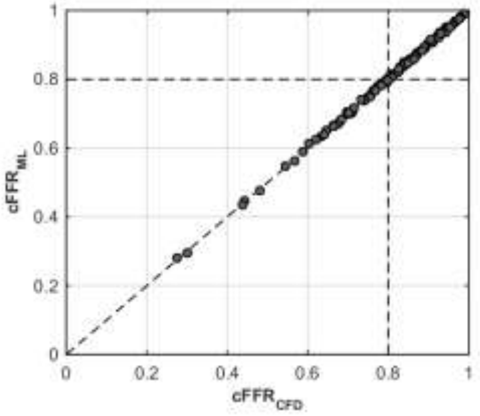
Deep-Learning based cFFR

Offline training phase



cFFR model

$$\mathbf{FFR(x)}$$

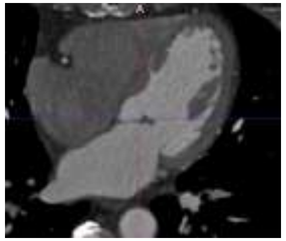


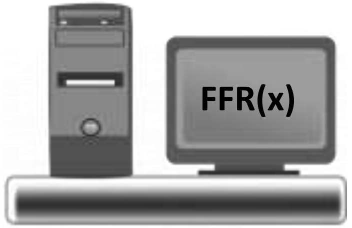
12,000 unique vessel trees with > 1,000,000 coronary segments

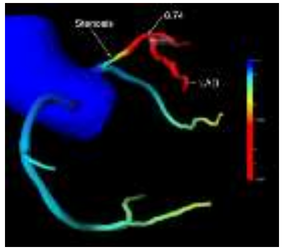
> 10 million locations with CFD based flow results

99.98% Correlation between deep-learning based cFFR and CFD

Deployment







Radiologist-driven workflow

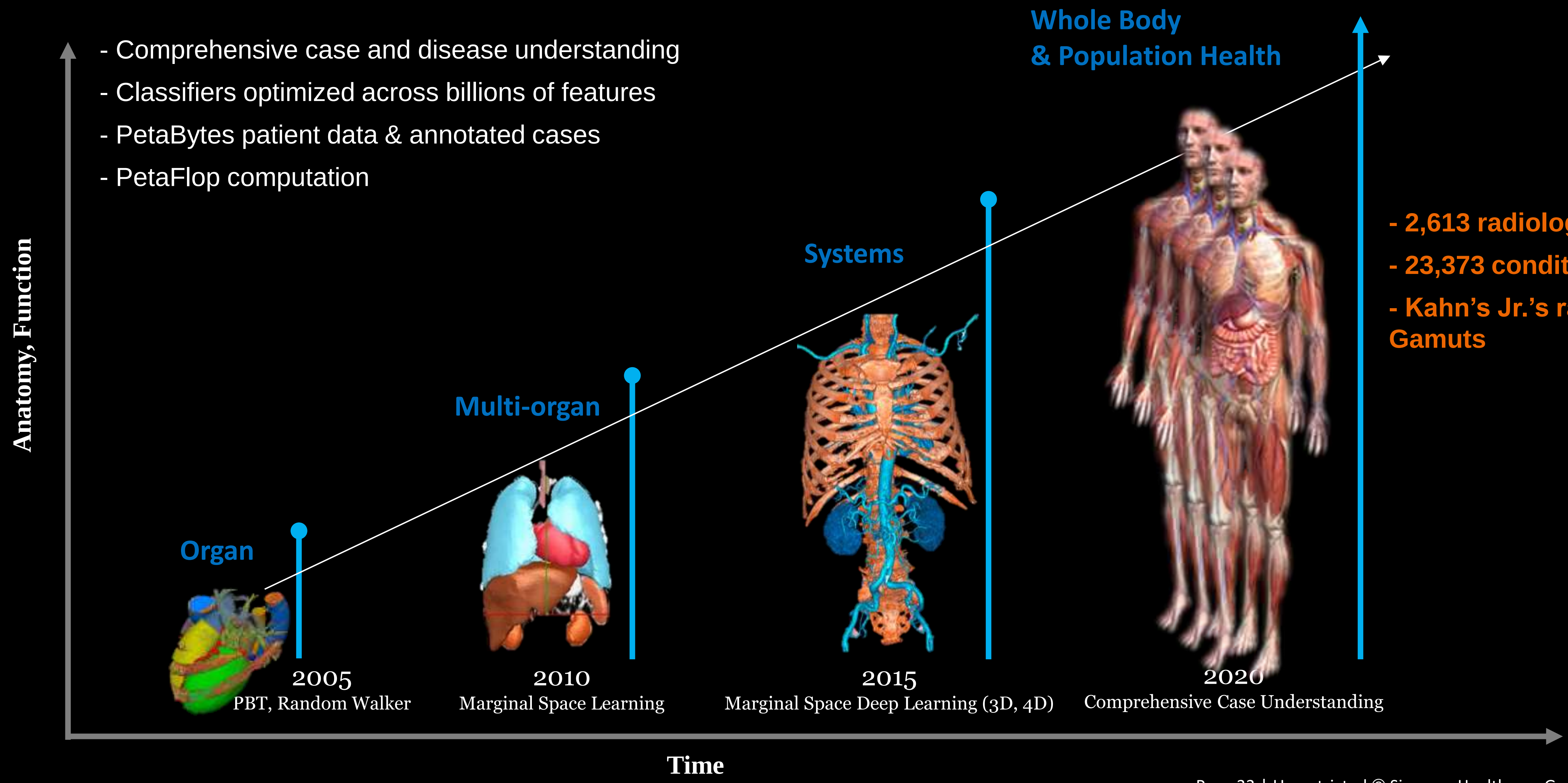
Workstation based

Real-time FFR update **after lumen correction/editing**

- Itu et al., A machine-learning approach for computation of fractional flow reserve from coronary computed tomography. J Appl Physiol 121: 42–52, 2016

From local analysis to whole body, population health and systems medicine

- Comprehensive case and disease understanding
- Classifiers optimized across billions of features
- PetaBytes patient data & annotated cases
- PetaFlop computation



- 2,613 radiology findings
- 23,373 conditions
- Kahn's Jr.'s radiology Gamuts

THANKS!

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https://www.siemens.com/us/en/home/company/jobs.html

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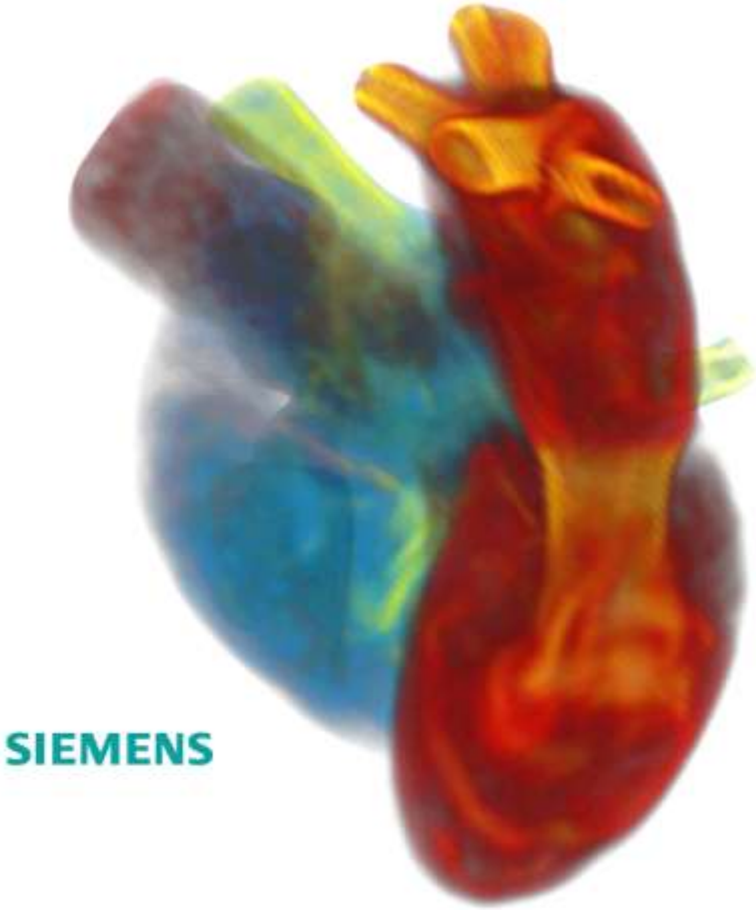
Towards Digital twin –
lifelong, personalized physiological model updated with each scan, exam



Patient-centric, holistic treatment

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Comaniciu et al, Shaping the Future through Innovations: From Medical Imaging to Precision Medicine, Medical Image Analysis, 2016.