Vessel Segmentation in Computed Tomography Scan of Lungs

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Challenge

VESSEL12

https://vessel12.grand-challenge.org/

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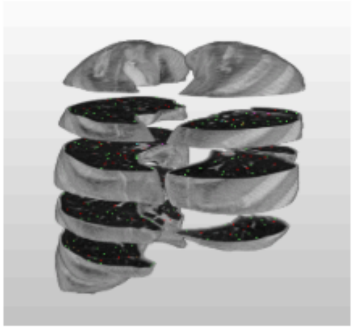
VESsel SEgmentation in the Lung 2012

The VESSEL12 challenge compares methods for automatic (and semi-automatic) segmentation of blood vessels in the lungs from CT images. The challenge is organized in conjunction with the IEEE International Symposium on Biomedical Imaging (ISBI 2012), held in Barcelona, Spain, from 2 to 5 May 2012.The results of this challenge will be presented during a workshop held in the morning of the first day of ISBI, May 2nd, Barcelona.



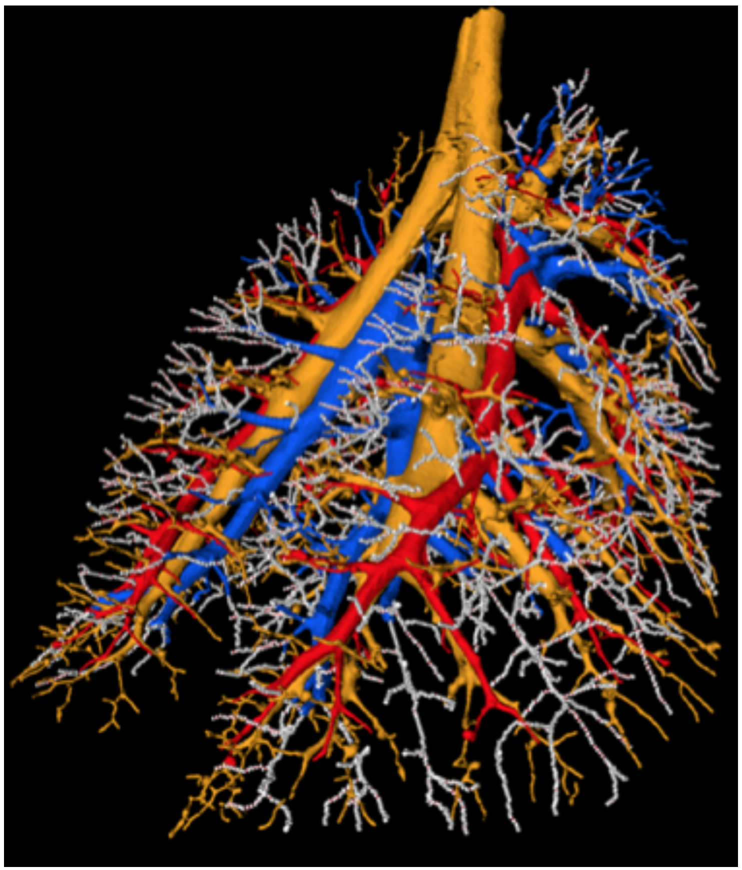
Who can participate?

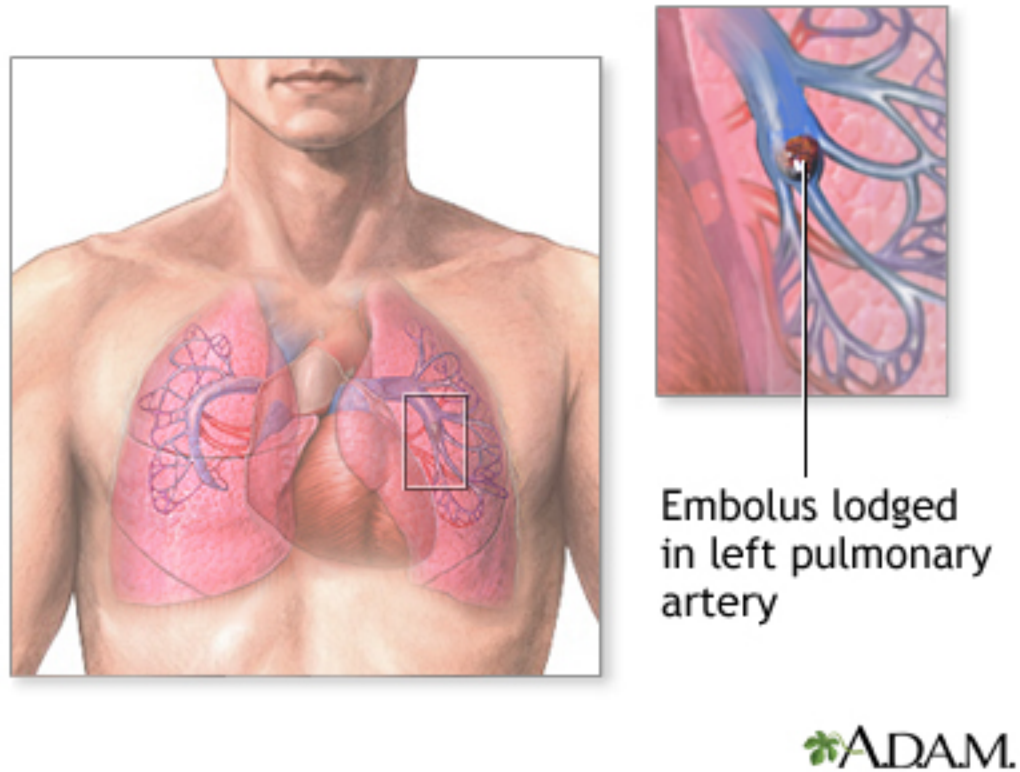
Any team, whether from academia or industry, can join.

How does it work?

After registering on this site, a team can download a number of CT-scans of the lungs. Each team then submits a probabilistic segmentation of the vessels in each scan, and a description of their algorithm. Each submission is evaluated against a reference standard. The evaluation results will be presented at the ISBI 2012 workshop and will be published on this site. After the workshop, an overview article with all teams as co-authors, will be compiled by the organizers of the challenge.

Rational





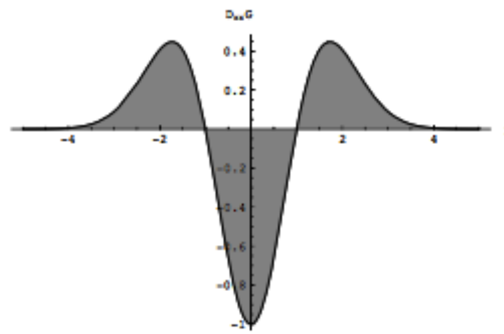
Measuring a Vessel

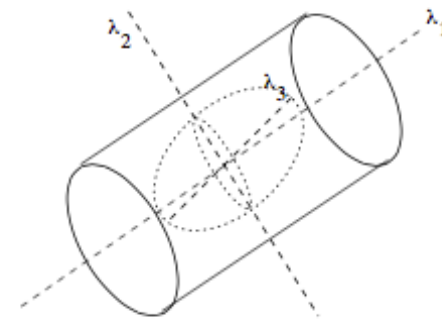
$$L(\mathbf{x}_o + \delta\mathbf{x}_o, s) \approx L(\mathbf{x}_o, s) + \delta\mathbf{x}_o^T \nabla_{o,s} + \delta\mathbf{x}_o^T \mathcal{H}_{o,s} \delta\mathbf{x}_o$$

$$\frac{\partial}{\partial x} L(\mathbf{x}, s) = s^{\gamma} L(\mathbf{x}) * \frac{\partial}{\partial x} G(\mathbf{x}, s)$$

$$G(\mathbf{x}, s) = \frac{1}{\sqrt{(2\pi s^2)^D}} \; e^{-\frac{\|\mathbf{x}\|^2}{2s^2}}$$

$$\delta\mathbf{x}_o^T \mathcal{H}_{o,s} \delta\mathbf{x}_o = \left(\frac{\partial}{\partial \delta\mathbf{x}_o}\right)\left(\frac{\partial}{\partial \delta\mathbf{x}_o}\right) L(\mathbf{x}_o, s)$$





A Frangi, et al., “Multiscale vessel enhancement filtering”, Proc. MICCAI, pp. 130-137, 1998.

Measuring a Vessel using Hessian

$$\mathcal{H}_{o,s}\hat{\mathbf{u}}_{s,k} = \lambda_{s,k}\hat{\mathbf{u}}_{s,k}$$

$$\mathcal{S} = \|\mathcal{H}\|_F = \sqrt{\sum_{j \leq D} \lambda_j^2}$$

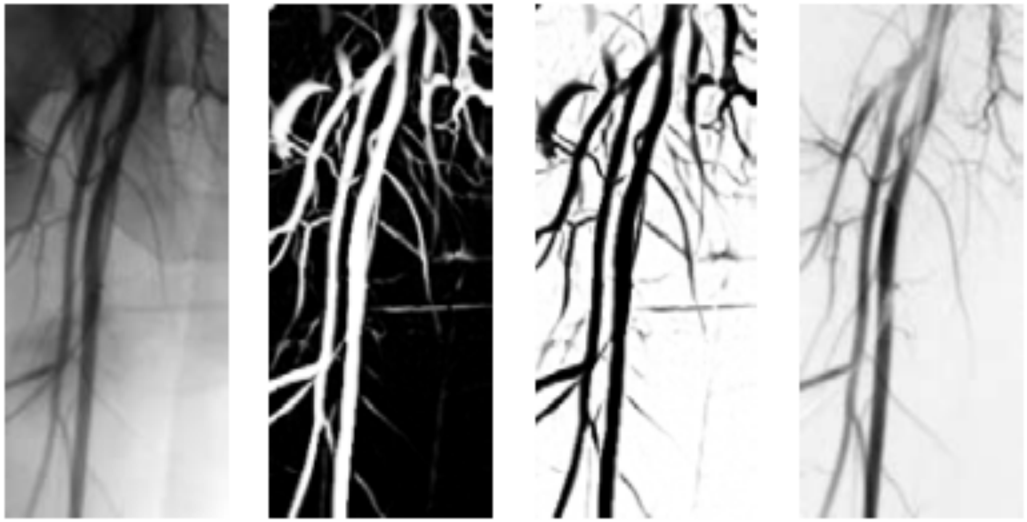
$$\hat{\mathbf{u}}_{s,k}^T \mathcal{H}_{o,s}\hat{\mathbf{u}}_{s,k} = \lambda_{s,k}$$

$$\mathcal{R}_{\mathcal{A}} = \frac{\text{(Largest Cross Section Area)}/\pi}{\text{(Largest Axis Semi-length)}^2} = \frac{|\lambda_2|}{|\lambda_3|}$$

$$\mathcal{R}_{\mathcal{B}} = \frac{\text{Volume}/(4\pi/3)}{\text{(Largest Cross Section Area}/\pi)^{3/2}} = \frac{|\lambda_1|}{\sqrt{|\lambda_2\lambda_3|}}$$

Vesselness Measure using Hessian

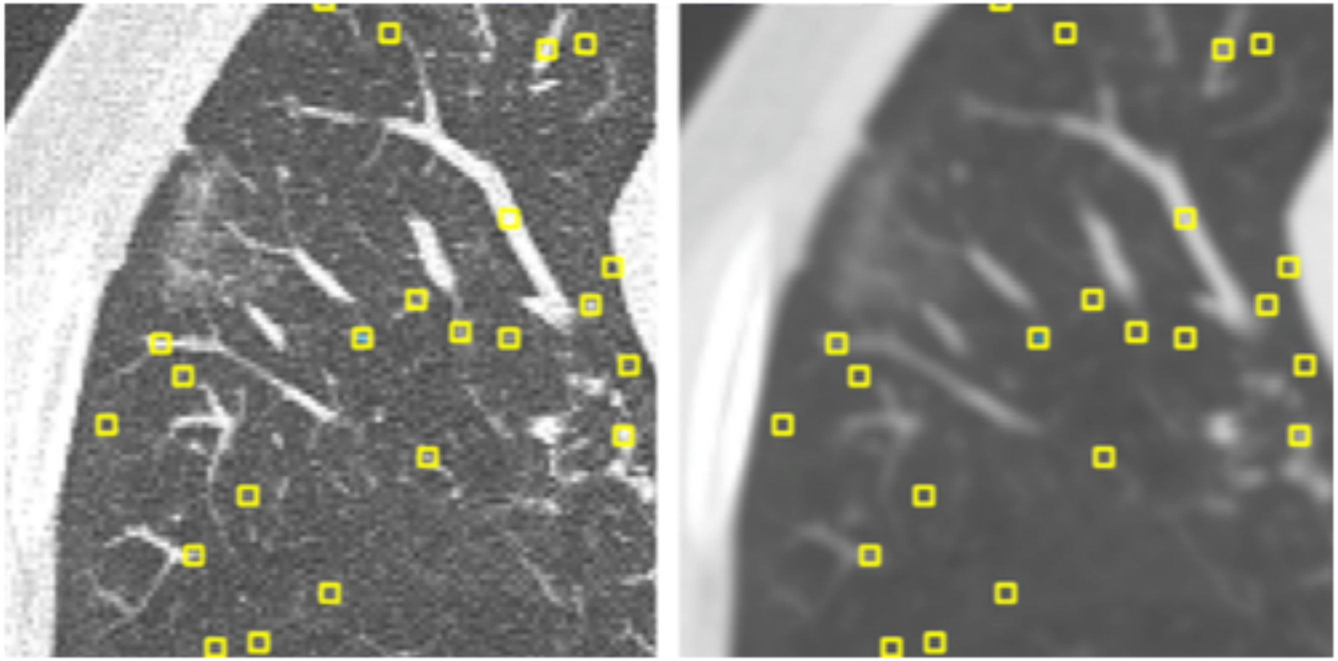
$$\mathcal{V}_o(s) = \begin{cases} 0 \\ \left(1 - \exp\left(-\frac{\mathcal{R_A}^2}{2\alpha^2}\right)\right) \exp\left(-\frac{\mathcal{R_B}^2}{2\beta^2}\right)\left(1 - \exp\left(-\frac{\mathcal{S}^2}{2c^2}\right)\right) \end{cases}$$



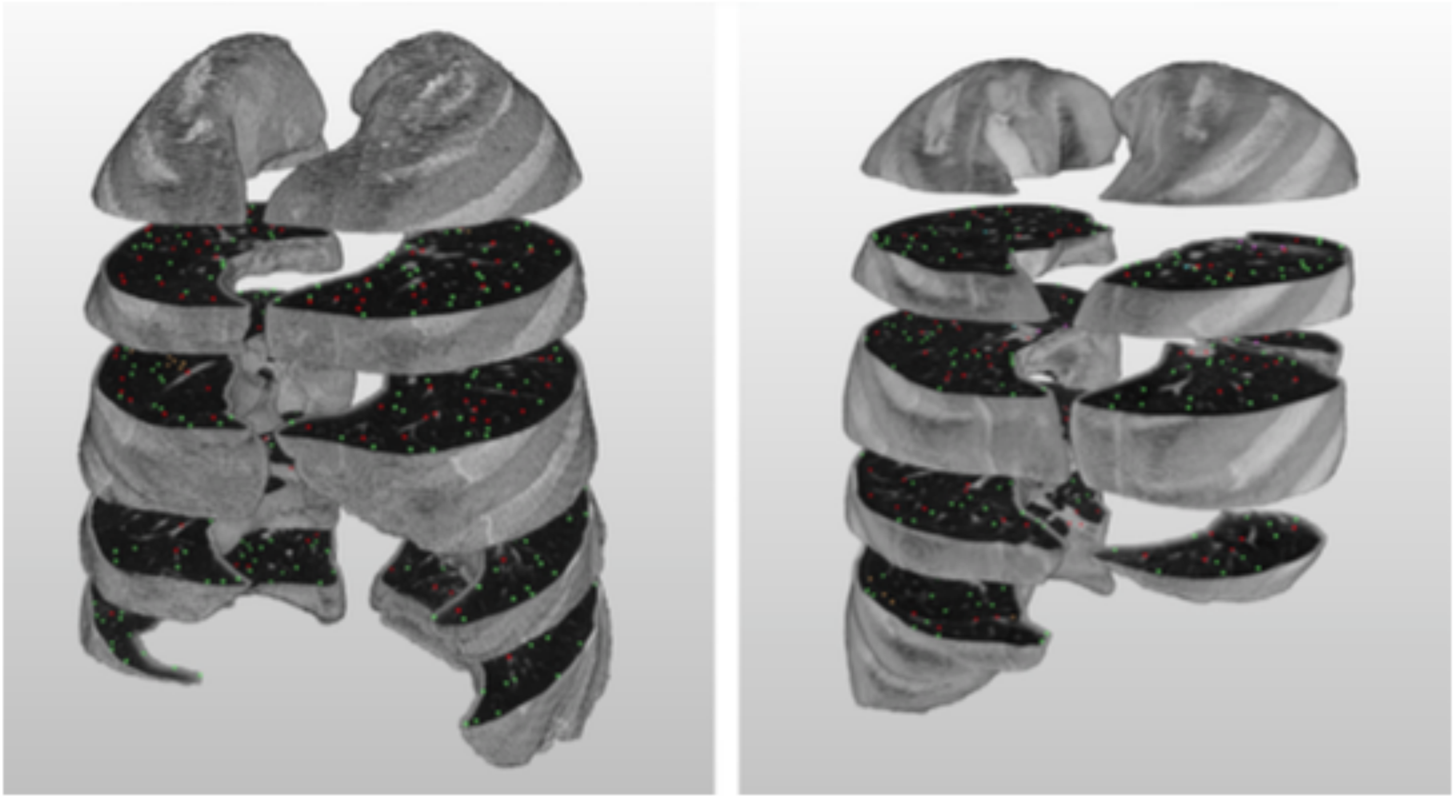
Dataset

Scan	Image type	Pathology	Scanner and kernel	Spacing (mm)	Z-spacing (mm)	# Of slices	kV/mAs
01	Angio-CT	Alveolar inflammation	Siemens SOMATOM Sensation 64, B60f	0.76	1	355	120/40
02	Chest CT	Alveolar inflammation	Philips Mx8000 IDT 16, B Kernel	0.71	0.7	415	140/74
03	Chest CT	ILD	Philips Mx8000 IDT 16, B Kernel	0.62	0.7	534	120/77
04	LD Chest CT	ILD	Toshiba Acquilion ONE, FC55	0.86	1	426	100/44[a]
05	Chest CT	ILD	Philips Mx8000 IDT 16, B Kernel	0.72	0.7	424	140/73
06	Angio-CT	ILD	Siemens SOMATOM Sensation 64, B30f	0.63	1	375	120/81
07	LD Chest CT	ILD	Toshiba Acquilion ONE, FC55	0.69	1	461	100/23[a]
08	Chest CT	ILD	Philips Mx8000 IDT 16, B Kernel	0.78	0.7	442	140/64
09	Angio-CT	ILD	Siemens SOMATOM Sensation 64, B25f	0.68	1	543	100/150
10	Angio-CT	ILD	Toshiba Acquilion ONE, FC83	0.88	1	426	120/68[a]
11	Angio-CT	ILD and emphysema	Toshiba Acquilion ONE, FC83	0.77	1	421	100/120
12	Angio-CT	Secondary pulmonary arterial hypertension	Toshiba Acquilion ONE, FC83	0.8	1	446	100/92[a]
13	Angio-CT	Pulmonary thromboembolism	Toshiba Acquilion ONE, FC83	0.89	1	471	120/117[a]
14	LD Chest CT	Pulmonary thromboembolism and emphysema	Toshiba Acquilion ONE, FC83	0.71	1	386	100/33[a]
15	Angio-CT	Pulmonary thromboembolism	Siemens SOMATOM Sensation 64, B25f	0.65	1	378	100/150
16	LD Chest CT	Small nodules	Toshiba Acquilion ONE, FC83	0.75	1	451	100/38[a]
17	Angio-CT	Nodules and diffuse abnormalities	Siemens SOMATOM Sensation 64, B25f	0.59	1	429	100/135
18	Chest CT	Normal	Philips Brilliance 16P, B Kernel	0.78	0.7	408	140/73
19	HR Chest CT	Small nodules	Toshiba Acquilion ONE, FC83	0.69	1	396	120/68[a]
20	LD Chest CT	Emphysema	Toshiba Acquilion ONE, FC55	0.75	1	406	100/32[a]

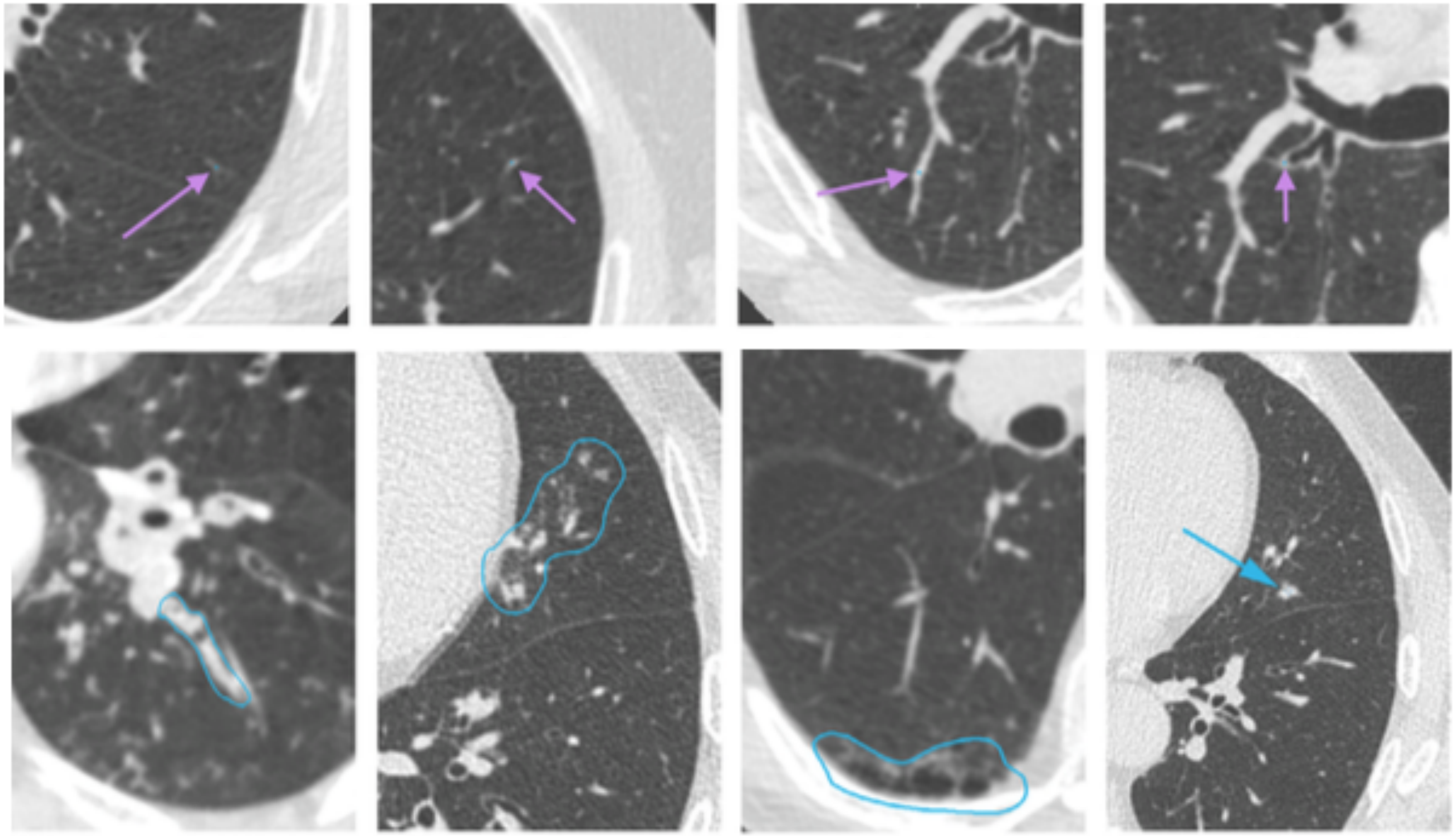
Vessel Appearances



3D Volume Appearance



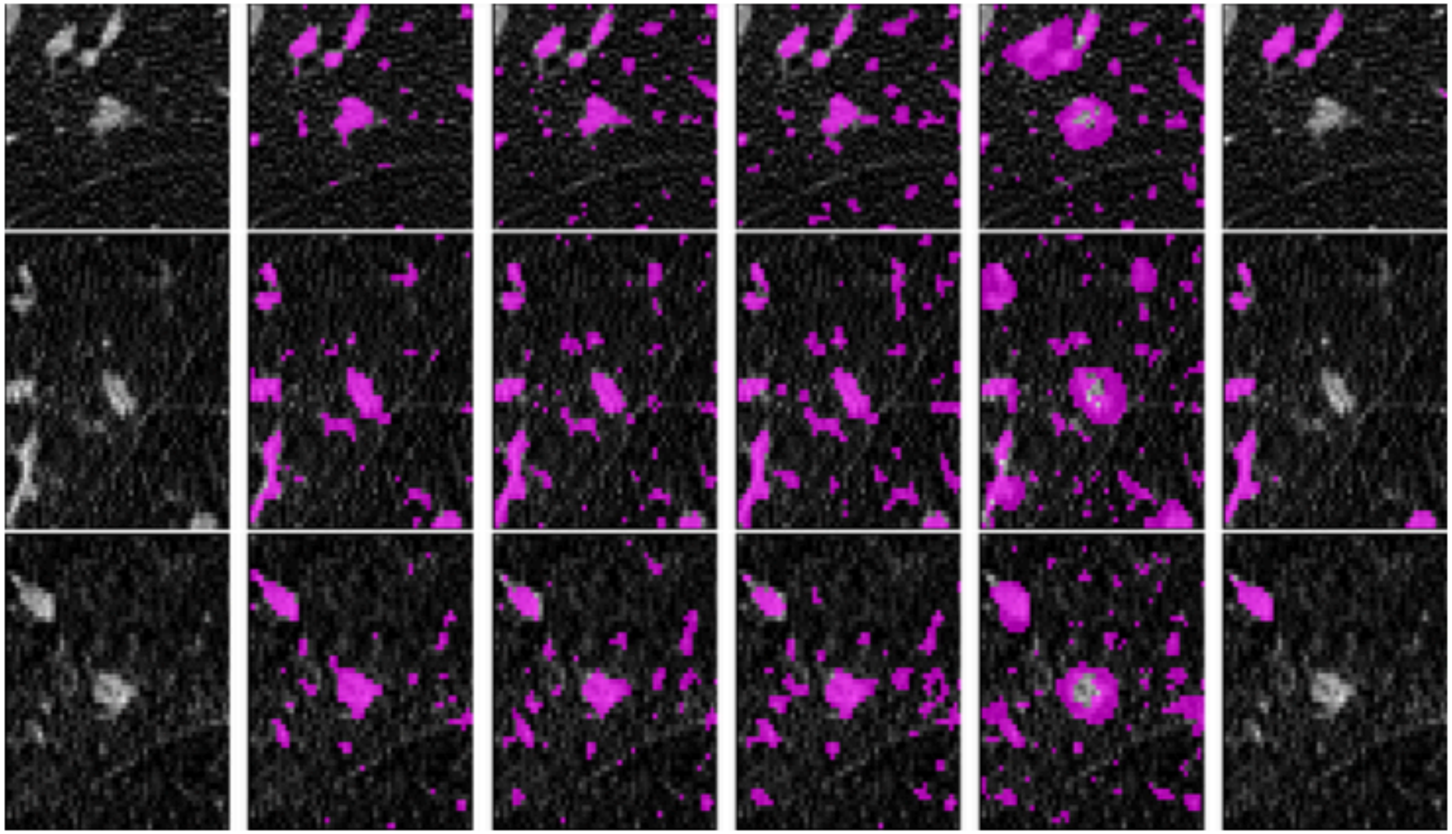
Appearance Diversity



Different Teams and Contribution

Team	Algorithm type	Multi-scale	Postprocessing
Probabilistic			
B	Thresholding	N/A	Airway wall and nodules removal
C	Hessian-based	No	Large low-vesselness structure removal
D	Hessian-based	Yes	No
E	Hessian-based	Yes	No
G	Hessian-based	Yes	Airway walls removal
H	Hessian-based	Yes	No
I	Hessian- and region growing-based	No	Airway walls removal
K	Hessian-based	Yes	Histogram equalization
L	Hessian-based	Yes	Histogram equalization
M	Hessian-based	Yes	Histogram equalization
N	Hessian-based	Yes	Histogram equalization
Q	Hessian-based	Yes	Histogram equalization
Binary			
F	Hessian- and region growing-based	Yes	No
J	Machine-learning	N/A	Large nodule removal
O	Region growing-based	N/A	Airway walls removal
P	Hessian-based	Yes	Airway walls and lobe fissure removal
Reference			
R1	Thresholding	N/A	No
R2	Hessian-based	Yes	No
Post-challenge submissions			
S	Machine-learning	Yes	No
T	Hessian-based	Yes	No
U	Hessian-based	Yes	No
V	Hessian- and region growing-based	Yes	*(Preprocessing)* Airway walls removal
W	Hessian- and region growing-based	Yes	Yes

Visual Manifestation



Take Home Messages

- R. D. Rudyanto, et al., "Comparing algorithms for automated vessel segmentation in computed tomography scans of the lung: the VESSEL12 study," Medical Image Analysis, vol. 18, pp. 1217–1232, 2014.