Can we combine computer aided diagnosis with radiologist expertise?

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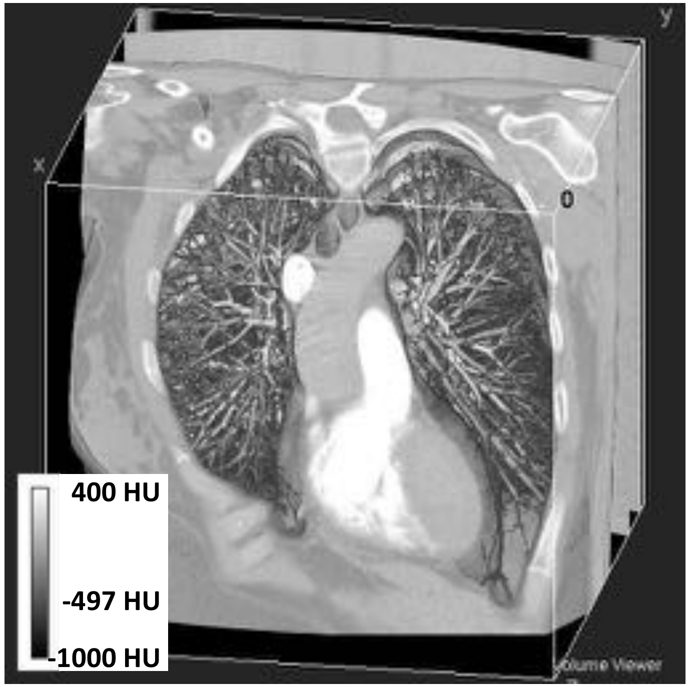

2016 - Image courtesy of M. Pienn, Z. Bálint, H. Olschewski

1. Computer aided diagnosis – CAD

- the use of computer algorithms to aid the image interpretation process
- used as computer aided/assisted detection, too

- (a) CAD should improve radiologists' performance
- (b) CAD should save time
- (c) CAD must be seamlessly integrated into the workflow
- (d) CAD should not impose liability concerns and the incremental cost

Computer-aided Diagnosis: How to Move from the Laboratory to the Clinic – Ginneken et al 2011 Radiology

1. Computer aided diagnosis – CAD

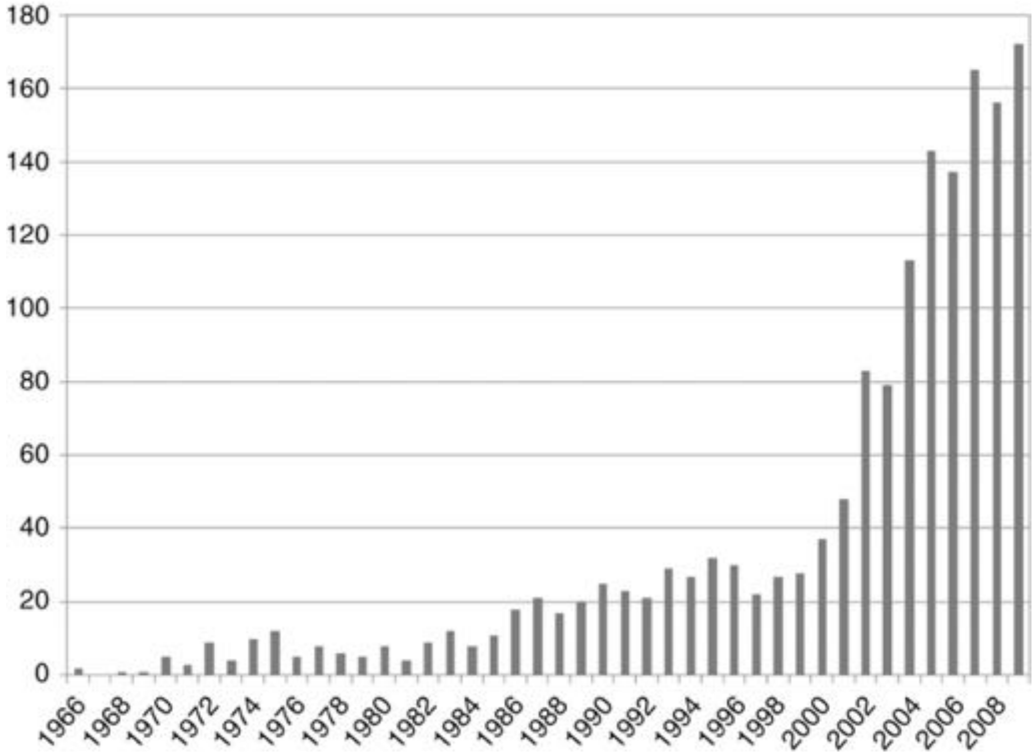

Figure 1: Graph shows number of publications on or related to CAD per year from 1966 through 2009 (last bar). Data were obtained from a PubMed search with search term "computer-aided diagnosis"[Title/Abstract] OR "computer-aided detection"[Title/Abstract] OR "computer-assisted diagnosis"[Title/Abstract] OR "computer-assisted detection"[Title/Abstract].

Computer-aided Diagnosis: How to Move from the Laboratory to the Clinic – Ginneken et al 2011 Radiology

1. Computer aided diagnosis – CAD

- Preprocessing
- Segmentation
- Candidate detection
- Feature extraction
- Classification
- System output

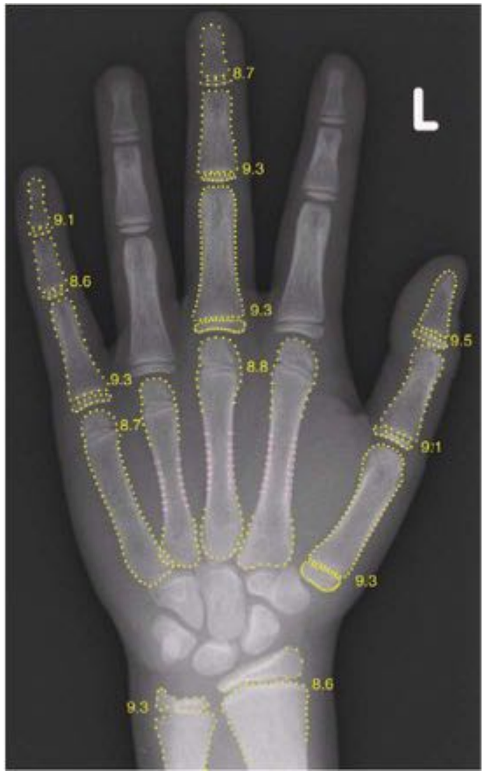

Figure 4: Radiograph of the left hand and wrist analyzed with BoneXpert. The program reconstructs the borders of 15 bones and estimates bone age for 13 bones, displayed. These are combined with a nonlinear function to obtain the Greulich Pyle bone age, 9.03 years for this case. Running time for the analysis was 4 seconds.

Computer-aided Diagnosis: How to Move from the Laboratory to the Clinic – Ginneken et al 2011 Radiology

Ludwig Boltzmann Institute
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http:/lvr.lbg.ac.at

Acknowledgements

Ludwig Boltzmann Institute
Lung Vascular Research

Christian Payer, Michael Helmberger
Michael Pienn
and the whole team of the LBI-LVR

Ludwig Boltzmann Institute
Clinical Forensic Imaging

Dr. Martin Urschler

LMU KLINIKUM DER UNIVERSITÄT MÜNCHEN

PD Dr. Thorsten Johnson
Dr. Felix Meinel
Dr. Caroline Burgard

Medical University of Graz

Prof. Horst Olschewski
Dr. Robert Neuwirth, Dr. Emine Talakic,
Dr. Carmen Salvan-Schaschl, Dr. Eszter Nagy

TU Graz

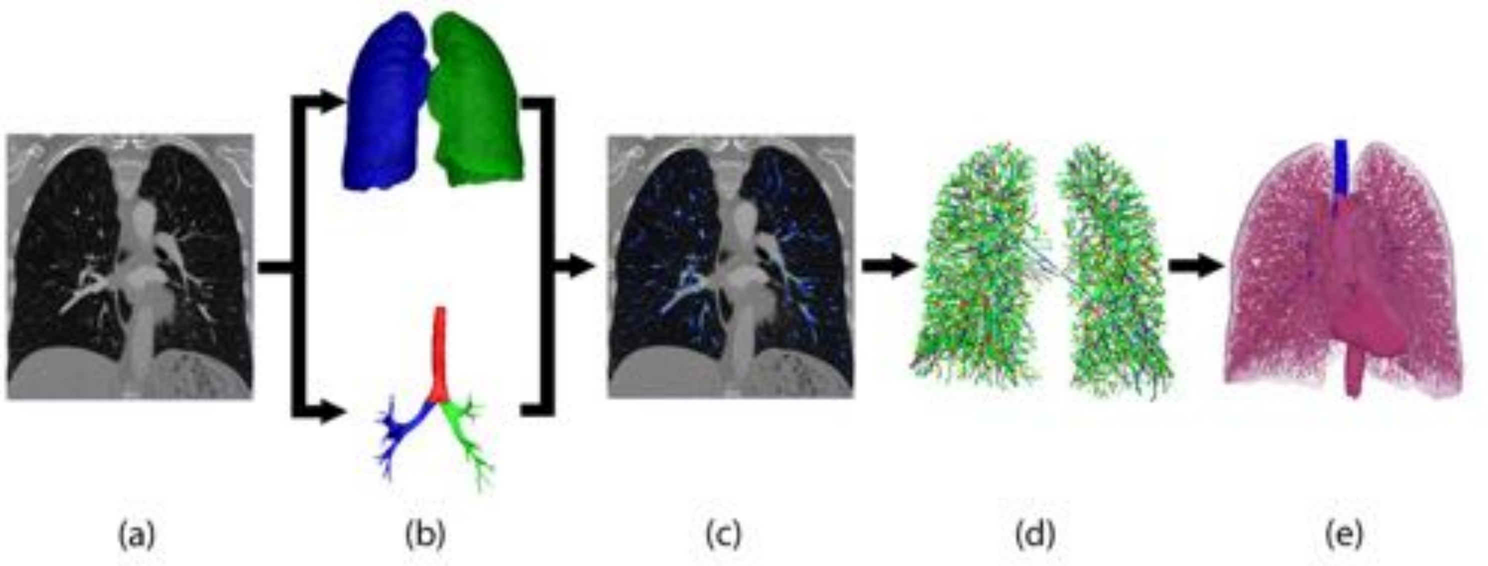
Prof. Rudolf Stollberger
Prof. Thomas Pock

DIAGNOSTIKZENTRUMGRAZ

Wolfgang Loidl
Univ.-Doz. Peter Kullnig

Software development for semi-automated CT image analysis

Aim: automatic extraction and analysis of lung vessels from computed tomography (CT) images



[1] Helmberger et al. (2014). Quantification of tortuosity and fractal dimension of the lung vessels in pulmonary hypertension patients. PLoS ONE.

Idea: automatic artery-vein separation 11.11.2013

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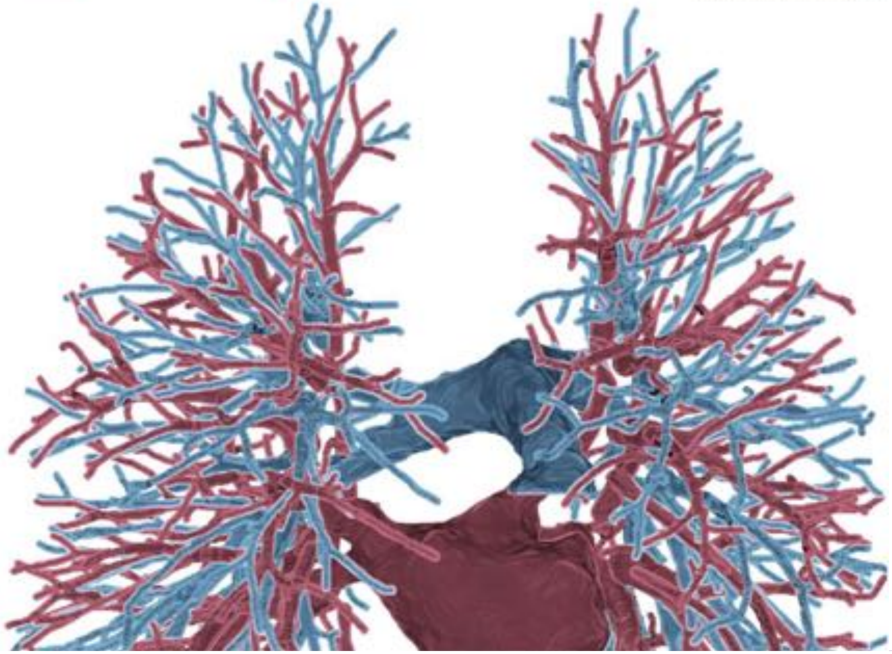
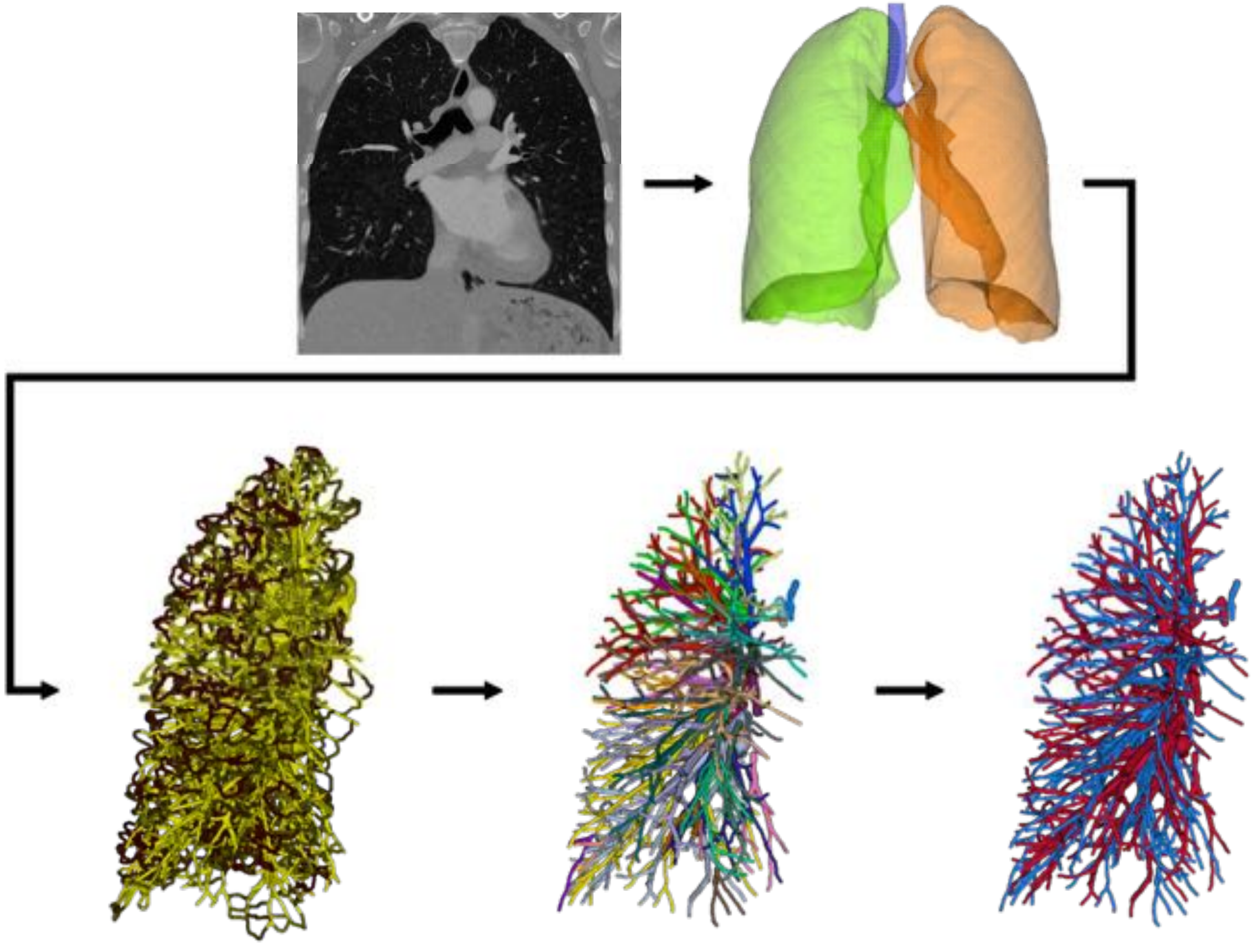
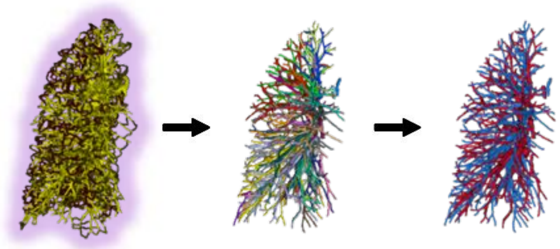


Algorithm overview



Payer C. et al.; (2015) MICCAI oral presentation
Pienn M. et al. ; (2015) MIUA oral presentation

4D path graph



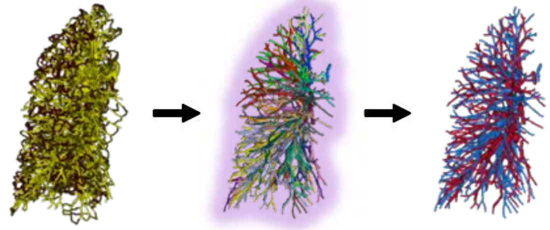
Goal:

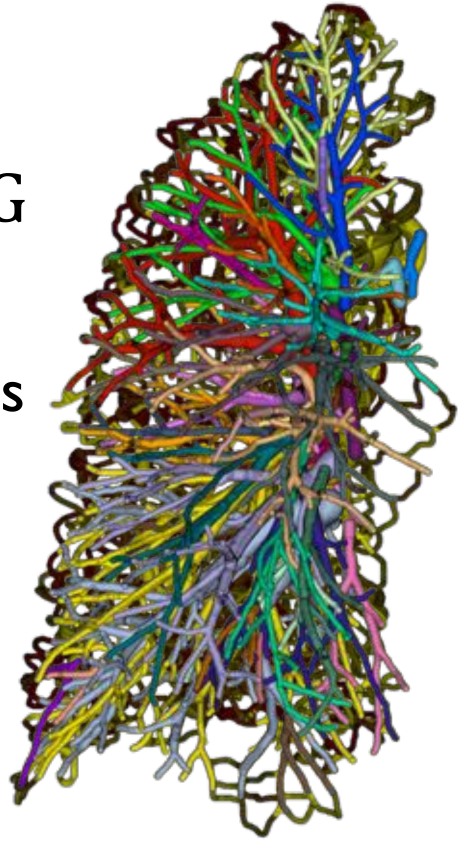
- create overcomplete vessel graph $G = (V, E)$
  - probable and improbable paths

Approach:

- 4D vessel enhancement
- local maxima graph
- 4D tubular paths

Subtree extraction





Goal:

- extract subtrees s_i from graph G
  - multiple subtrees
  - no distinction of arteries and veins

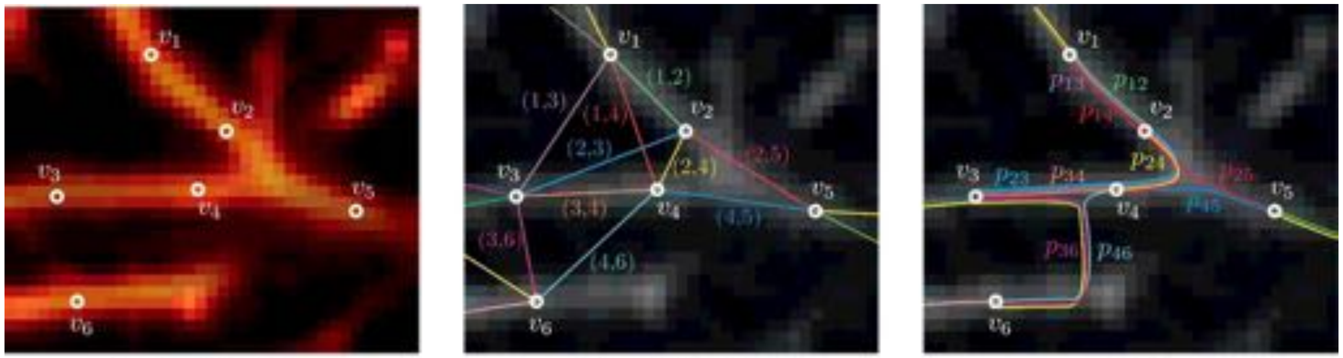
Approach:

- integer program
  - geometric relationship of paths
  - implicit root detection

Geometric relationship of paths

Weight for adjoining path pairs:

1. short geodesic distance
   - tube-like structures
2. high orientation similarity
   - no abrupt direction changes
3. decreasing radius
   - from proximal to distal vessels



(a) Local maxima (b) Neighbor edges (c) Paths

Geometric relationship of paths

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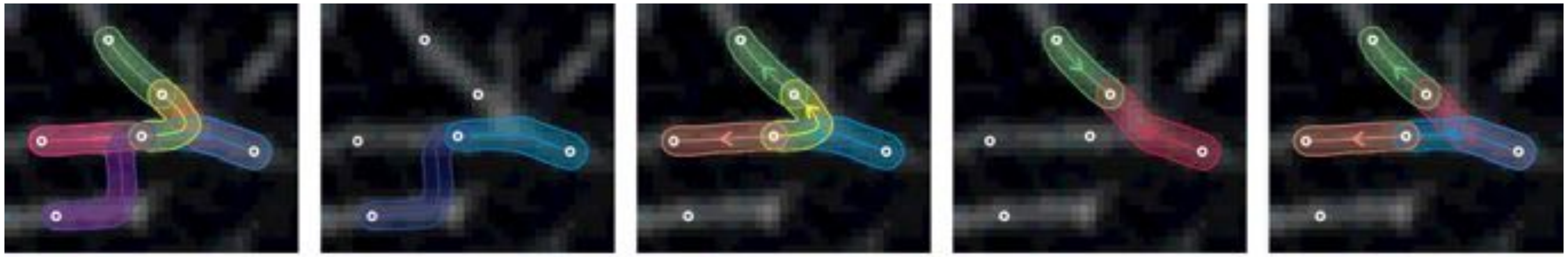
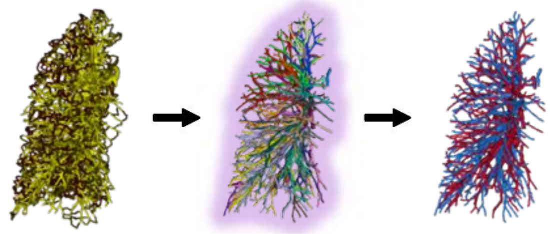


(a) Example path graph (b) Large distance weight (c) Large direction weight (d) Large radius weight (e) Extracted subtree

A/V labeling of subtrees

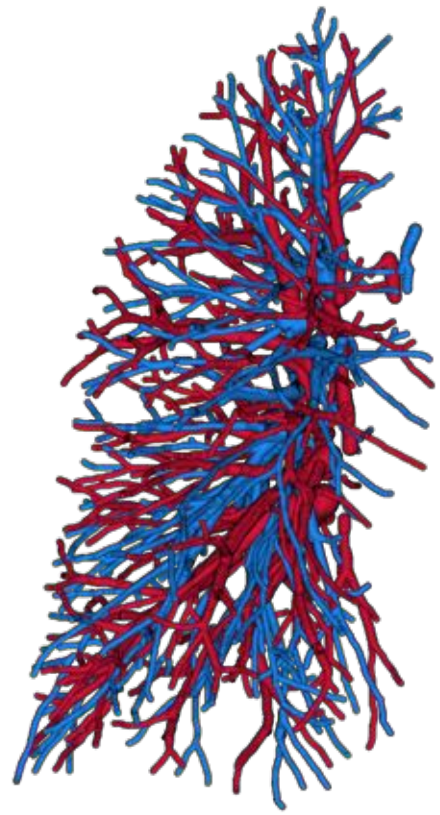


Goal:

- label each extracted subtree s_i as artery or vein

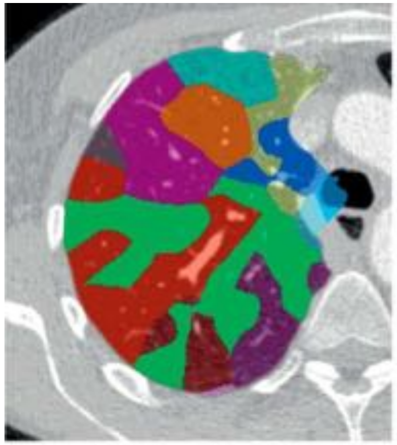
Approach:

- integer program
- use two anatomical properties
  - uniform distribution of A/V
  - proximity of arteries and bronchi

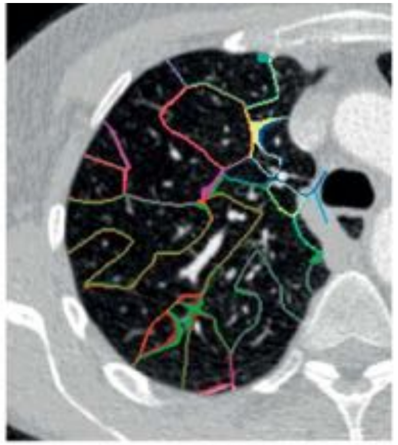


Uniform distribution of A/V

- calculate generalized Voronoi diagram
  - estimate nearest subtree for every voxel
- maximize the contact surface of the Voronoi regions
  - encourages uniform distribution



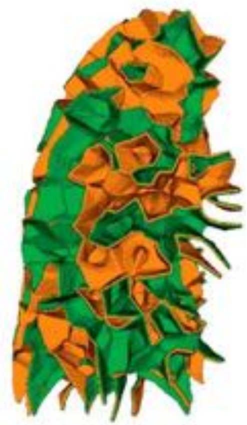
(a) Slice of a GVD



(b) Slice of GVD borders

(c) GVD

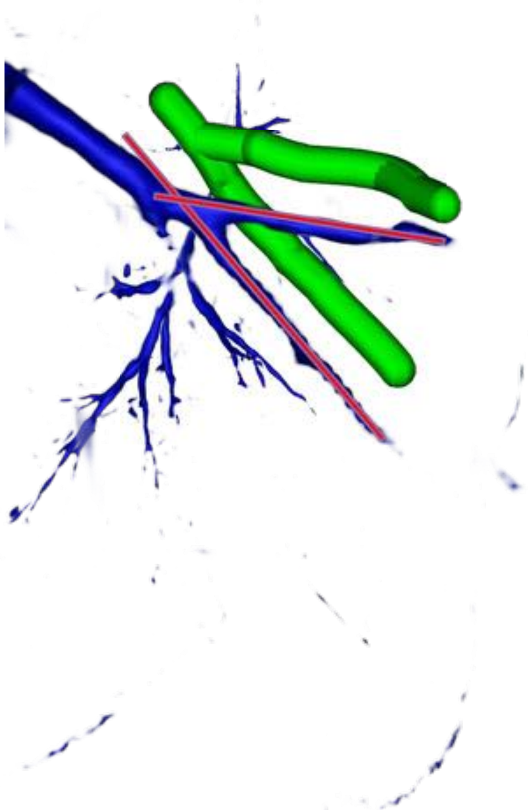
(d) GVD borders



(e) GVD borders maximizing area

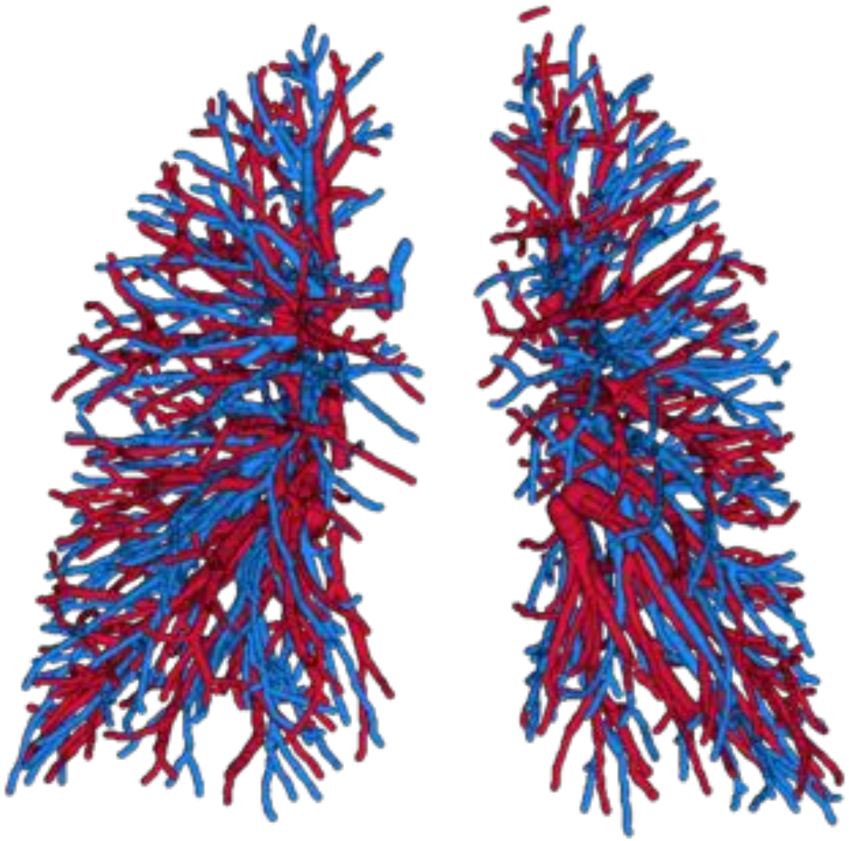
Proximity of arteries and bronchi

- “arterialness” per vessel segment
- bronchus enhancement
  - similar to vessel enhancement
- identify bronchus points close to vessels
- fit line through detected points
- final measure based on orientation and proximity



Results

fully automatic artery/vein separation from CT volumes



arteries: blue
veins: red

Payer C. et al.; (2015) MICCAI oral presentation
Pienn M. et al. ; (2015) MIUA oral presentation

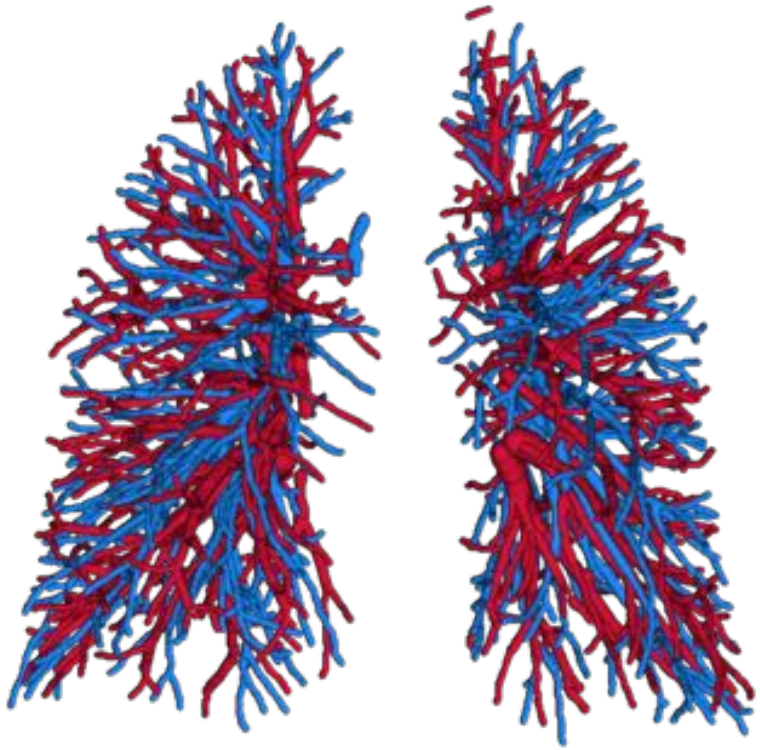
Evaluation

25 datasets with manual A/V segmentation
- size: approx. 512x512x512 voxel
- voxel: approx. 0.6x0.6x0.6 mm

methods evaluated:
- proposed method
- state-of-the-art semi automatic (Park et al.)

Results

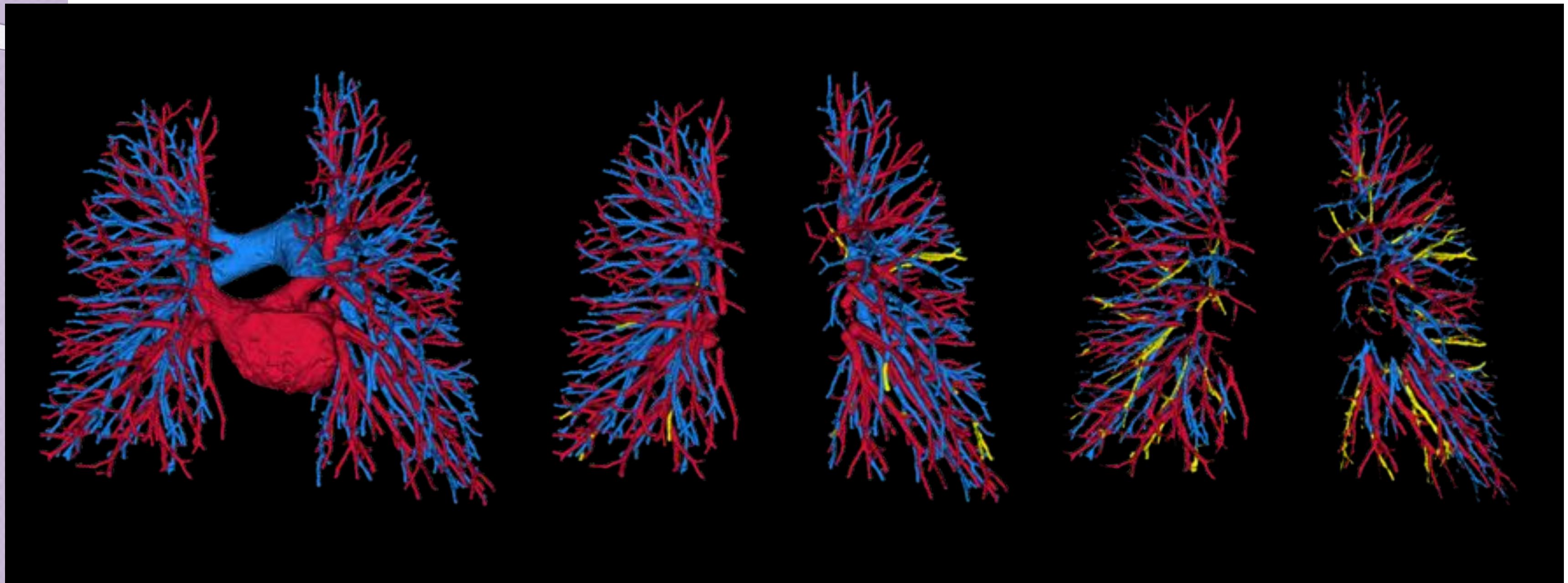
manual segmentation of 25 data sets for validation:
E. Talakic, E. Nagy, D. Scherjau, C. Payer



arteries: blue
veins: red

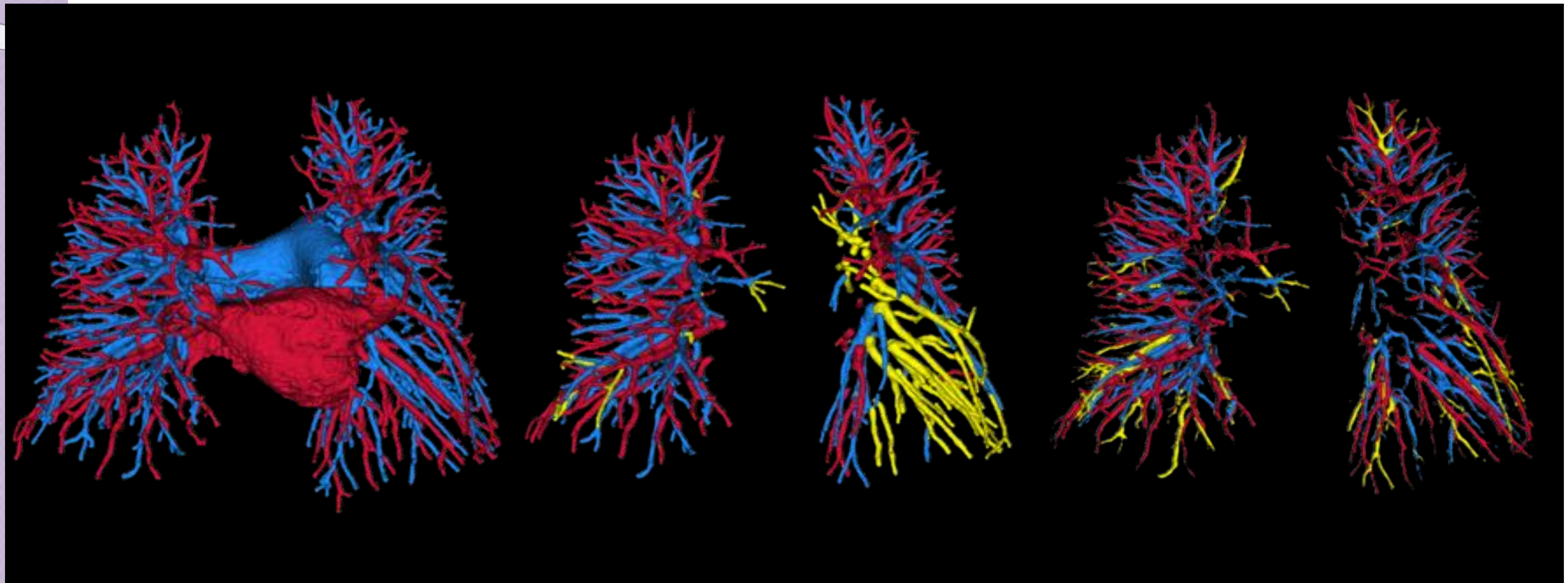
Payer C. et al. LNCS (2015) 9350

Overlap with manual segmentation



Manual reference Proposed method Park et al.

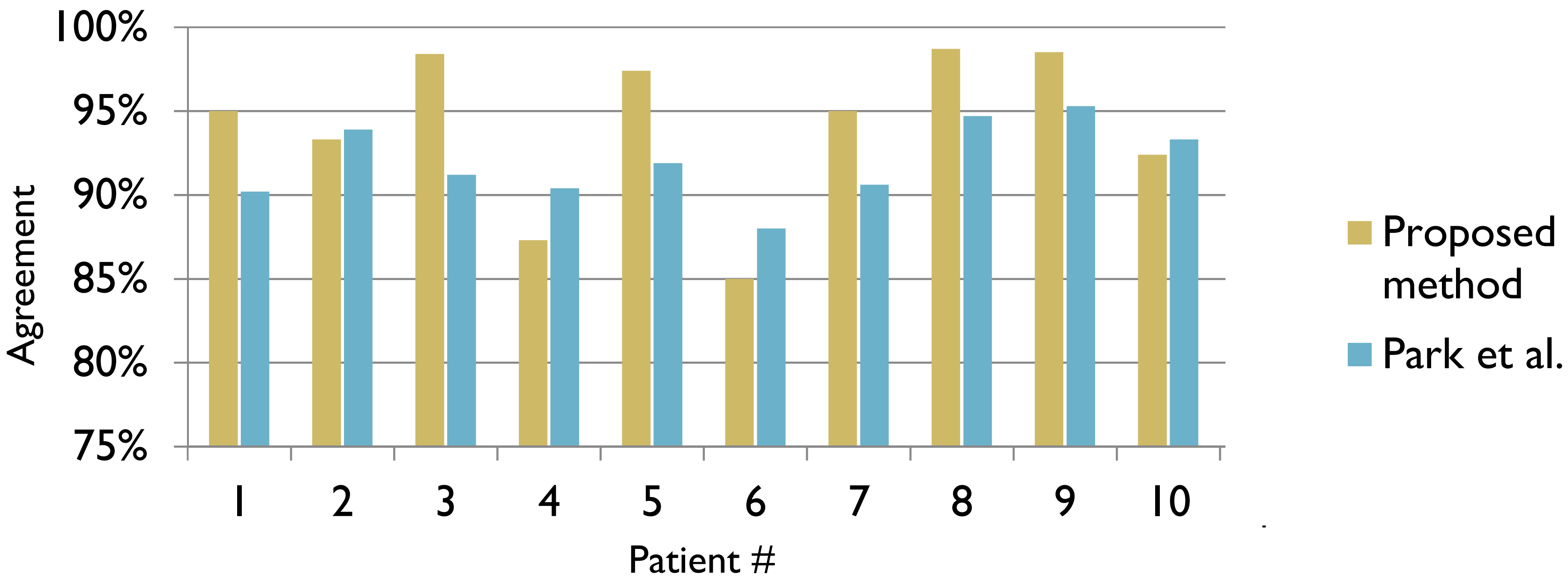
Overlap with manual segmentation



Manual reference　　Proposed method　　Park et al.

Overlap with manual segmentation

$$\text{agreement} = \frac{|A_{ref} \cap A_{test}| + |V_{ref} \cap V_{test}|}{|(A_{ref} \cup V_{ref}) \cap (A_{test} \cup V_{test})|}$$

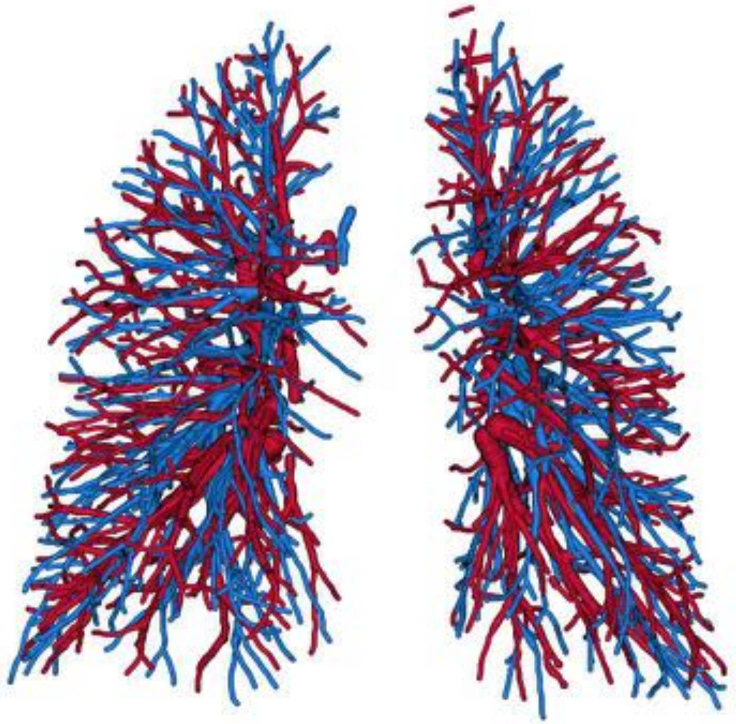


Results of the A/V separation project

- Oral presentation - C. Payer

  „**M**edical **I**mage **C**omputing and **C**omputer **A**ssisted **I**nterventions“[1]

- C. Payer - MSc defense in 2015 at TU Graz
- Invited article - Medical Image Analysis (Top 1, Rank 3) [2]



arteries: blue
veins: red

[1] Payer et al. (2015). Automatic Artery-Vein Separation from Thoracic CT Images Using Integer Programming. MICCAI 2015.

[2] Payer C., Pienn M, **Bálint Z**, Shekhovtsov A, Talakic E, Nagy E, Olschewski A, Olschewski H, Urschler M. 2016. Automated integer programming based separation of arteries and veins from thoracic CT images. *Medical image analysis* 2016 Dec; 34:109-122.

Martin Wurm – Diploma student (08.2013 - 07.2014)
Michael Pienn – PhD student
Pius Sonnberger – MSc student - project (07.2014 – 09.2014)
Zoltán Bálint – group leader
Christian Payer – MSc student (till 07.2015)

Michael Helmberger – MSc Student (till 2013)
Horst Olschewski – supporting scientist

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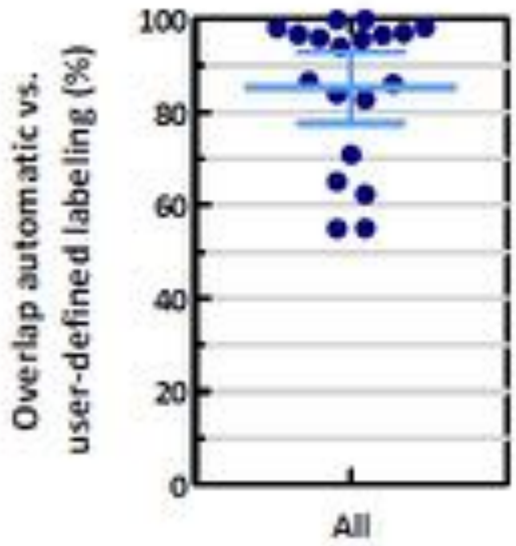
2. Radiological validation

2 radiologists (C. Salvan-Schaschl and R. Neuwirth, Graz), blinded to patient clinical data, performed user defined labeling on the results of the automatic algorithm



	All
Number of values	19
Minimum	54.90
25% Percentile	70.78
Median	93.92
75% Percentile	96.92
Maximum	99.92
Mean	85.17
Std. Deviation	15.69

Pienn M. et al.; (2016) ATS poster

2. Radiologist expertise

- LMU Munich example
  – nr. Radiologist - nr. CT/MRI per day
  – workload/CAD to help - 10 -15 min diagnosis

Project: Image denoising and iodine quantification from dual-energy CT images

Aim: - provide radiologists better quality images to facilitate diagnosis

- Develop software for noise reduction and iodine quantification from lung CT images

Image denoising and iodine quantification from dual-energy CT images

Validation/Evaluation in clinical setting

- Try and error in the validation setup
- Quantitative OK – physicist calculated
- Radiological validation – Siemens algorithm preferred
- **Project on hold**

3. we combine…

Trust:

"Because humans and computers make decisions in a different way, it is sometimes difficult for a human to understand why an automated aid has made a certain decision."

Jorritsma et al 2015 Clinical Radiology

Patent story – LBI-LVR, Graz

- Idea - 2010
- Patent – priority 2011, filing 2012AT, 2014EU/US-Publication 2015
- Tech offer for companies – no interest raised
- Scientific article - 2014
- No Company – No investment - 2017

M. Pienn, Z. Bálint, H. Olschewski, R. Stollberger, G. Kovacs. *Methode z. Nichtinvasiven Diagnose von Pulmonaler Hypertonie* – Patent Application No. AU 512393/2013 **filed 29th June 2012**, issued 13th August 2013; PCT/AT2013/050127 filed 25th June 2013.

M. Pienn, Z. Bálint, H. Olschewski, R. Stollberger, G. Kovacs. *Method for Processing Images of Pulmonary Circulation and Device for Performing the Method* – Patent Publication No. US 2015/0206303-A1, **issue date 23rd July 2015**.

M. Pienn, Z. Bálint, H. Olschewski, R. Stollberger, G. Kovacs. *Methode z. Nichtinvasiven Diagnose von Pulmonaler Hypertonie* – Patent Application No. EU 13737520.0 filed 19th December 2014; EU Patent 2867856 **issue date 6th May 2015**.

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Proiect co-finanţat din Fondul European de Dezvoltare Regională prin Programul Operaţional Competitivitate 2014-2020

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Nr. contract de finanțare: 23/01.09.2016
POC: P_37_245, mySMIS: 104004

Beneficiar: SPITALUL CLINIC JUDEŢEAN DE URGENŢĂ CLUJ-NAPOCA
Director de proiect: Dr. Zoltán Bálint

Acțiunea 1.1.4 Atragerea de personal cu competențe avansate din străinătate pentru consolidarea capacității de CD

Proiect co-finanţat din Fondul European de Dezvoltare Regională prin Programul Operaţional Competitivitate 2014-2020