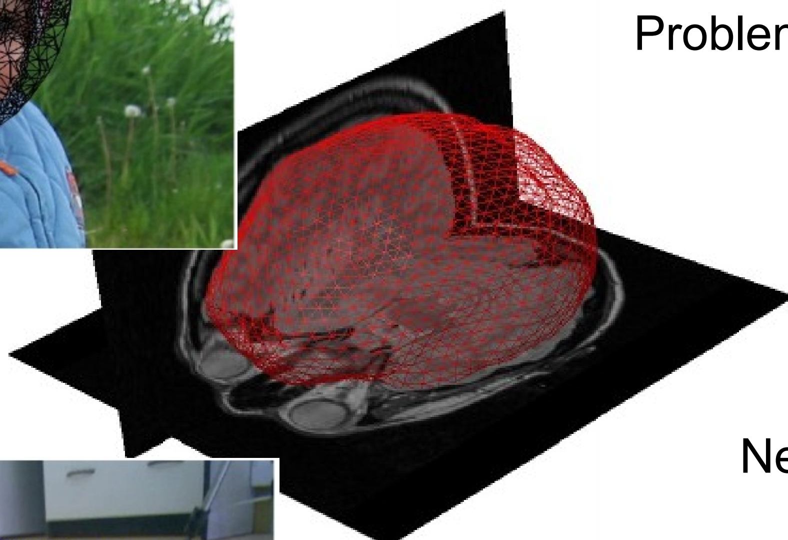
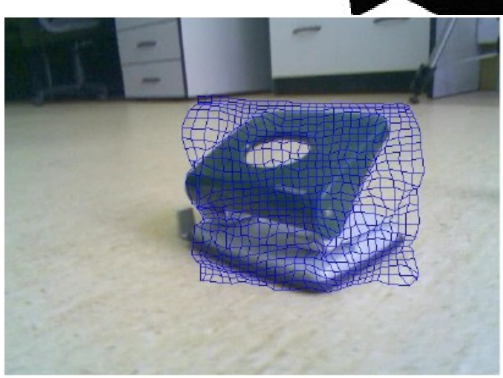
Computer analyses of 2D and 3D images in biomedical and food science domains

Piotr M. Szczypiński

NIST, Gaithersburg, 2016.08.04

Deformable models
General model for tensions modeling





KWT approach

$$E=\int_j \int_i \left(E_e(i,j)+E_i(i,j)\right)\mathrm{d}i\,\mathrm{d}j$$

$$E_i=\tau\left[\left|\frac{\partial \mathbf{v}}{\partial i}\right|^2+\left|\frac{\partial \mathbf{v}}{\partial j}\right|^2\right]+\rho\left[\left|\frac{\partial^2 \mathbf{v}}{\partial i^2}\right|^2+2\left|\frac{\partial^2 \mathbf{v}}{\partial i\,\partial j}\right|^2+\left|\frac{\partial^2 \mathbf{v}}{\partial j^2}\right|^2\right]$$

Problem statement

$$\begin{bmatrix}\sum \hat{x}^2 & \sum \hat{x}\hat{y} & \sum \hat{x}\\ \sum \hat{x}\hat{y} & \sum \hat{y}^2 & \sum \hat{y}\\ \sum \hat{x} & \sum \hat{y} & \sum 1\end{bmatrix}\begin{bmatrix}j_{11}\\ j_{12}\\ t_1\end{bmatrix}=\begin{bmatrix}\sum \hat{x}x\\ \sum \hat{y}x\\ \sum x\end{bmatrix}$$

$$\begin{bmatrix}\sum \hat{x}^2 & \sum \hat{x}\hat{y} & \sum \hat{x}\\ \sum \hat{x}\hat{y} & \sum \hat{y}^2 & \sum \hat{y}\\ \sum \hat{x} & \sum \hat{y} & \sum 1\end{bmatrix}\begin{bmatrix}j_{12}\\ j_{21}\\ t_2\end{bmatrix}=\begin{bmatrix}\sum \hat{x}y\\ \sum \hat{y}y\\ \sum y\end{bmatrix}$$

New solution

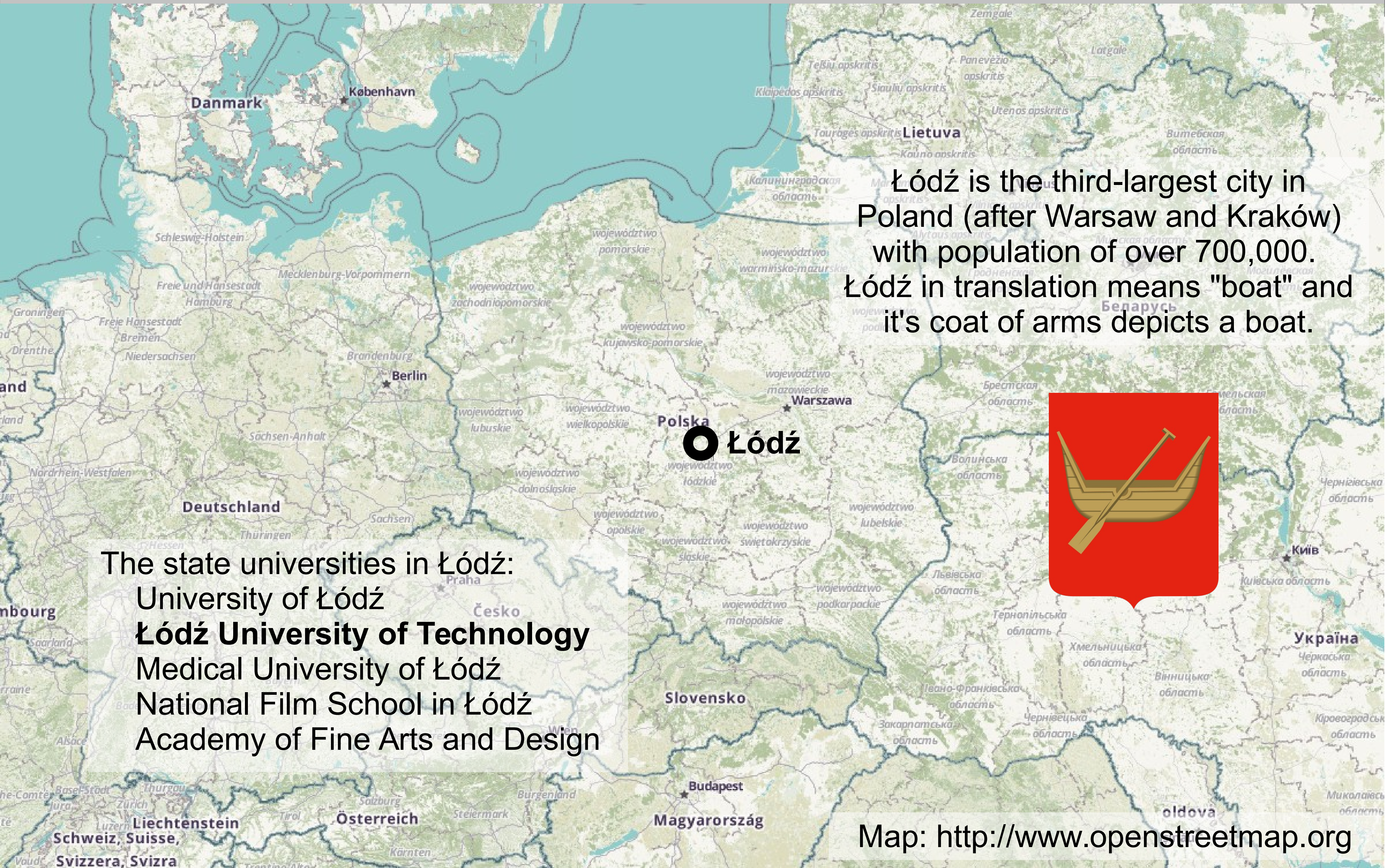
$$\begin{bmatrix}j_{11}\\ j_{12}\\ t_1\end{bmatrix}=\mathbf{M}\begin{bmatrix}\sum \hat{x}x\\ \sum \hat{y}x\\ \sum x\end{bmatrix};\quad \begin{bmatrix}j_{21}\\ j_{22}\\ t_2\end{bmatrix}=\mathbf{M}\begin{bmatrix}\sum \hat{x}y\\ \sum \hat{y}y\\ \sum y\end{bmatrix}$$

$$\mathbf{M}=\frac{\begin{bmatrix}\sum \hat{y}^2\sum 1-\left(\sum \hat{y}\right)^2 & \sum \hat{y}\sum \hat{x}-\sum \hat{x}\hat{y}\sum 1 & \sum \hat{x}\hat{y}\sum \hat{y}-\sum \hat{y}^2\sum \hat{x}\\ \sum \hat{y}\sum \hat{x}-\sum \hat{x}\hat{y}\sum 1 & \sum \hat{x}^2\sum 1-\left(\sum \hat{x}\right)^2 & \sum \hat{x}\hat{y}\sum \hat{x}-\sum \hat{x}^2\sum \hat{y}\\ \sum \hat{x}\hat{y}\sum \hat{y}-\sum \hat{y}^2\sum \hat{x} & \sum \hat{x}\hat{y}\sum \hat{x}-\sum \hat{x}^2\sum \hat{y} & \sum \hat{x}^2\sum \hat{y}^2-\left(\sum \hat{x}\hat{y}\right)^2\end{bmatrix}}{\sum \hat{x}^2\sum \hat{y}^2\sum 1-\left(\sum \hat{y}\right)^2\sum \hat{x}^2-\left(\sum \hat{x}\hat{y}\right)^2\sum 1-\left(\sum \hat{x}\right)^2\sum \hat{y}^2+2\sum \hat{y}\sum \hat{x}\sum \hat{x}\hat{y}}$$

Szczypiński P, Materka A. „Geometryczne modele deformowalne do analizy i rozpoznawania obrazów. Problemy Metrologii Elektronicznej i Fotonicznej", Oficyna Wydawnicza Politechniki Wrocławskiej, 2013;6:175-212

Łódź
Lodz

Łódź is the third-largest city in Poland (after Warsaw and Kraków) with population of over 700,000. Łódź in translation means "boat" and it's coat of arms depicts a boat.



The state universities in Łódź:

- University of Łódź
- **Łódź University of Technology**
- Medical University of Łódź
- National Film School in Łódź
- Academy of Fine Arts and Design

Map: http://www.openstreetmap.org

Łódź
Lodz

Thaddeus Kosciuszko monument, Washington DC

The Puck Building, New York City

Tadeusz Kościuszko monument, Plac Wolności (Liberty Square), the exact center of Łódź

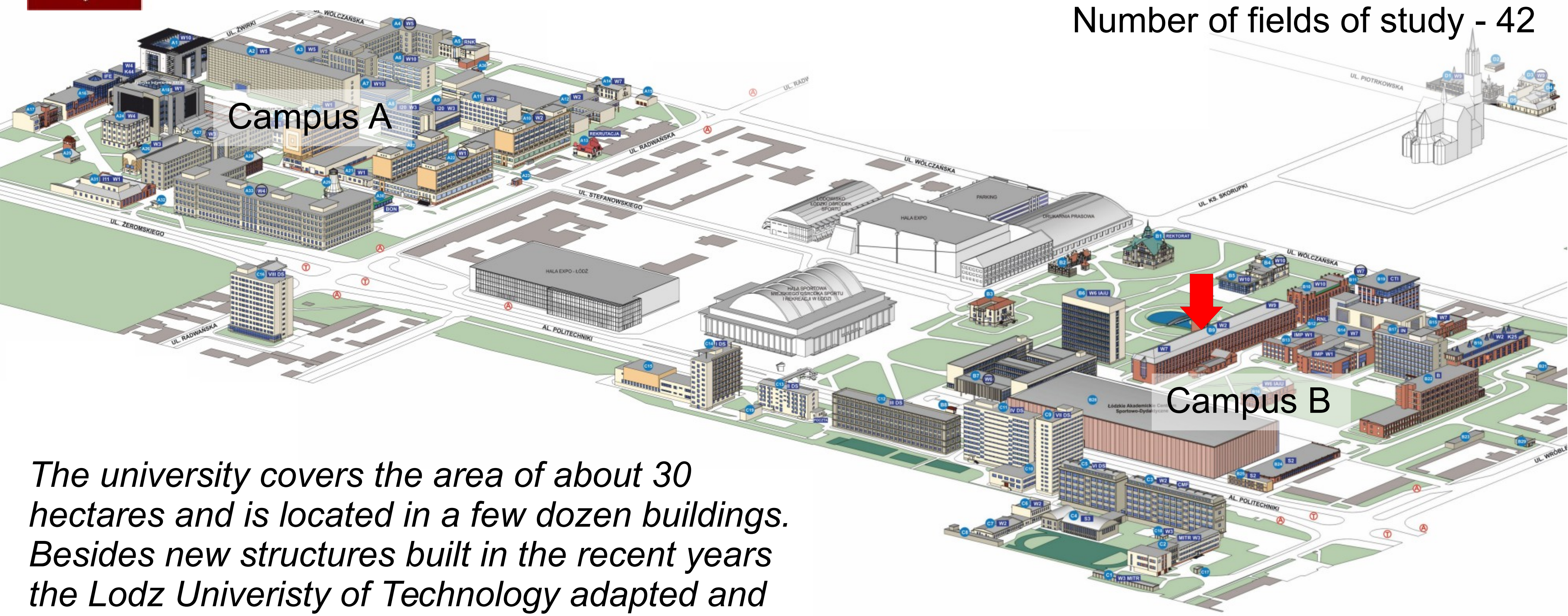
Manufaktura shopping center in Łódź

Images: wikipedia commons

Politechnika Łódzka
Lodz University of Technology

Politechnika Łódzka

Year of founding - 1945
Total number of staff - 2 829
Number of academic staff (professors) - 1 356 (245)
Number of students B.Sc, M.Sc (Ph.D) - 18 698 (677)
Number of fields of study - 42



The university covers the area of about 30 hectares and is located in a few dozen buildings. Besides new structures built in the recent years the Lodz Univeristy of Technology adapted and revitalized a few historic 19th century villas and factory buildings, adjusting them to its needs.

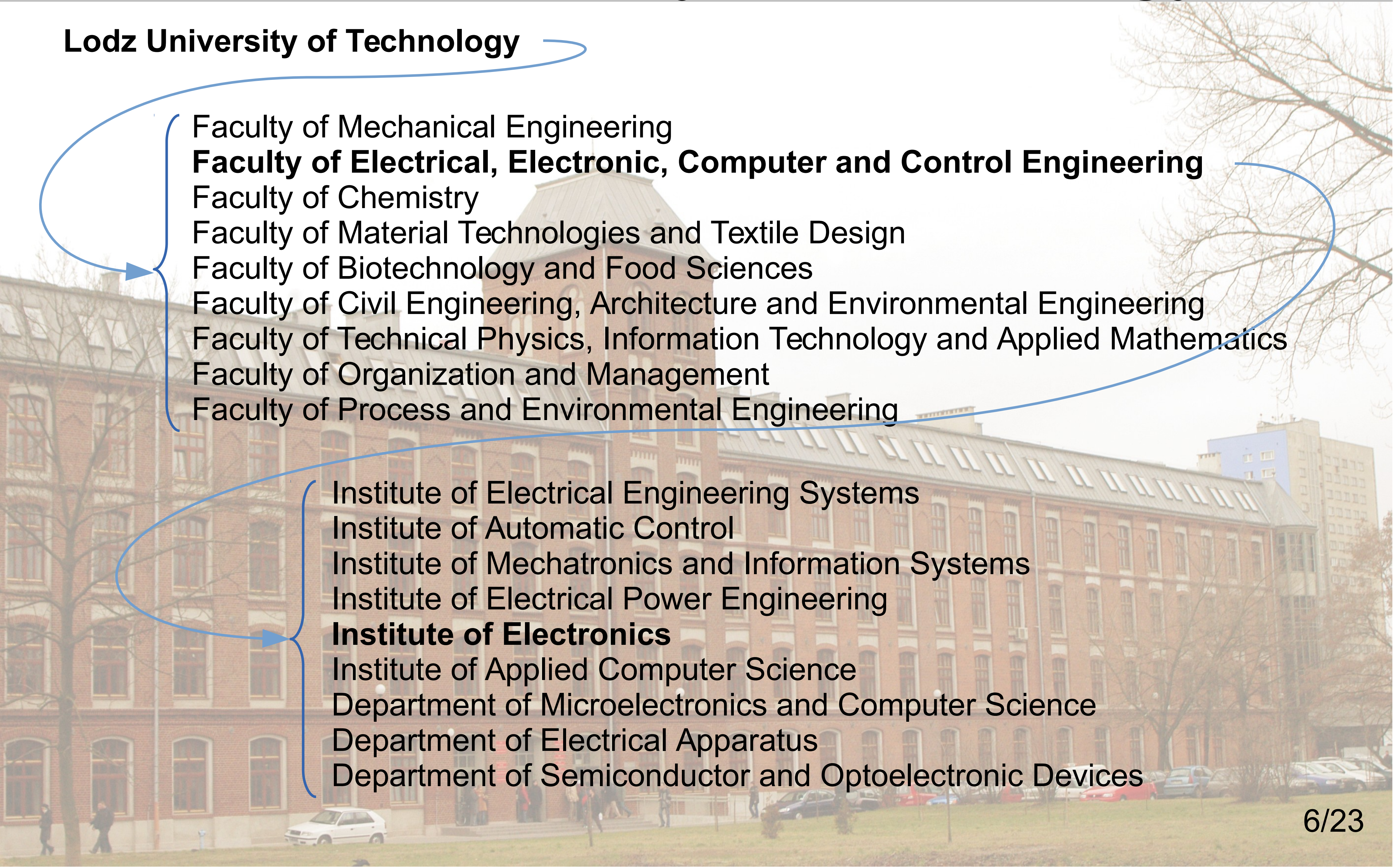
http://www.p.lodz.pl/

Politechnika Łódzka
Lodz University of Technology

Lodz University of Technology

- Faculty of Mechanical Engineering
- **Faculty of Electrical, Electronic, Computer and Control Engineering**
- Faculty of Chemistry
- Faculty of Material Technologies and Textile Design
- Faculty of Biotechnology and Food Sciences
- Faculty of Civil Engineering, Architecture and Environmental Engineering
- Faculty of Technical Physics, Information Technology and Applied Mathematics
- Faculty of Organization and Management
- Faculty of Process and Environmental Engineering

- Institute of Electrical Engineering Systems
- Institute of Automatic Control
- Institute of Mechatronics and Information Systems
- Institute of Electrical Power Engineering
- **Institute of Electronics**
- Institute of Applied Computer Science
- Department of Microelectronics and Computer Science
- Department of Electrical Apparatus
- Department of Semiconductor and Optoelectronic Devices



Institute of Electronics

The Director:
prof. dr hab. inż. Paweł Strumiłło

dr hab. inż. Piotr Szczypinski

dr inż. Marcin Kociołek

http://www.eletel.p.lodz.pl/

Instytut Elektroniki
Institute of Electronics

Medical Electronics Division

Processing and analysis of biomedical images and signals
Design of systems supporting people with disabilities
Electronic systems for biosignals measurement and data transmission
Human-computer interfaces, brain-computer interfaces
Programming and computations (machine learning, process modeling and simulations)

Telecommunications Division

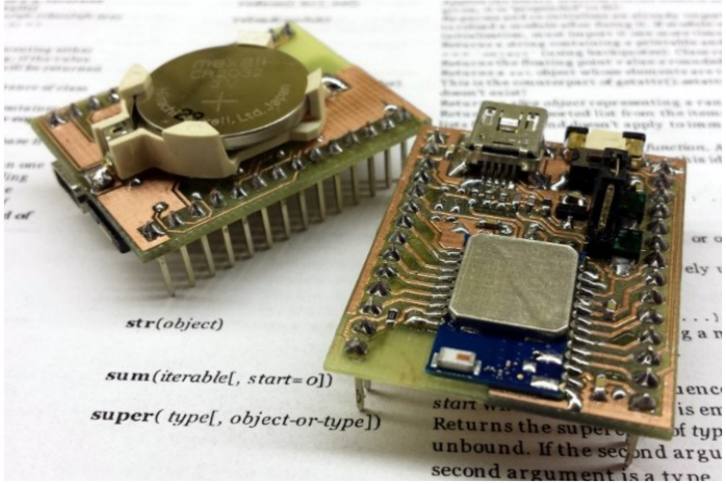
Propagation of radio waves modeling
Antennas and wireless communication systems design and measurements
Body area network design, body sensors
Radio wave localization systems
Applications of computational intelligence in ICT networks and optimization
Modeling, design and testing of specialized integrated circuits

Electronic Circuits and Thermography Division

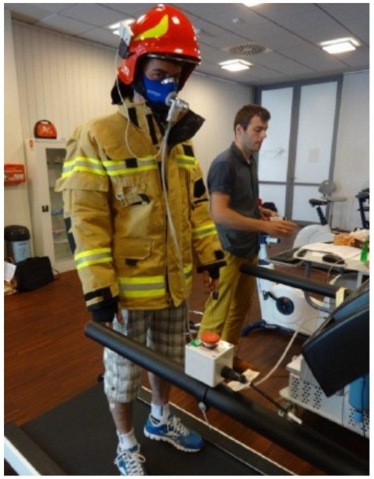
Applications of high sensitivity bolometric sensors and cameras
Measurements of thermal impedance
Analysis of thermal processes and electromagnetic phenomena in electronic micro-structures
Thermal issues inverse problem solutions
Human skin thermal modeling

Institute of Electronics
Student Research Groups

MIPSA - Embedded Systems Student Research Group



TELIN - Telecommunication, Electronics and Informatics Student Research Group



My research

Food quality

- Wheat grain drying effects
- Potato varieties recognition
- Barley variety recognition
- Barley quality assessment
- Cold meats quality evaluation

Medical diagnosis

- Heart ventricles modeling
- Human organs diagnosis
- Endoscopy diagnosis support
- Blood vessel tree modeling
- MR angiography simulation

Algorithms development

- Deformable models
- Image segmentation
- 3D modeling
- Texture and color analysis
- Discriminant analysis
- Data conversion

Programing

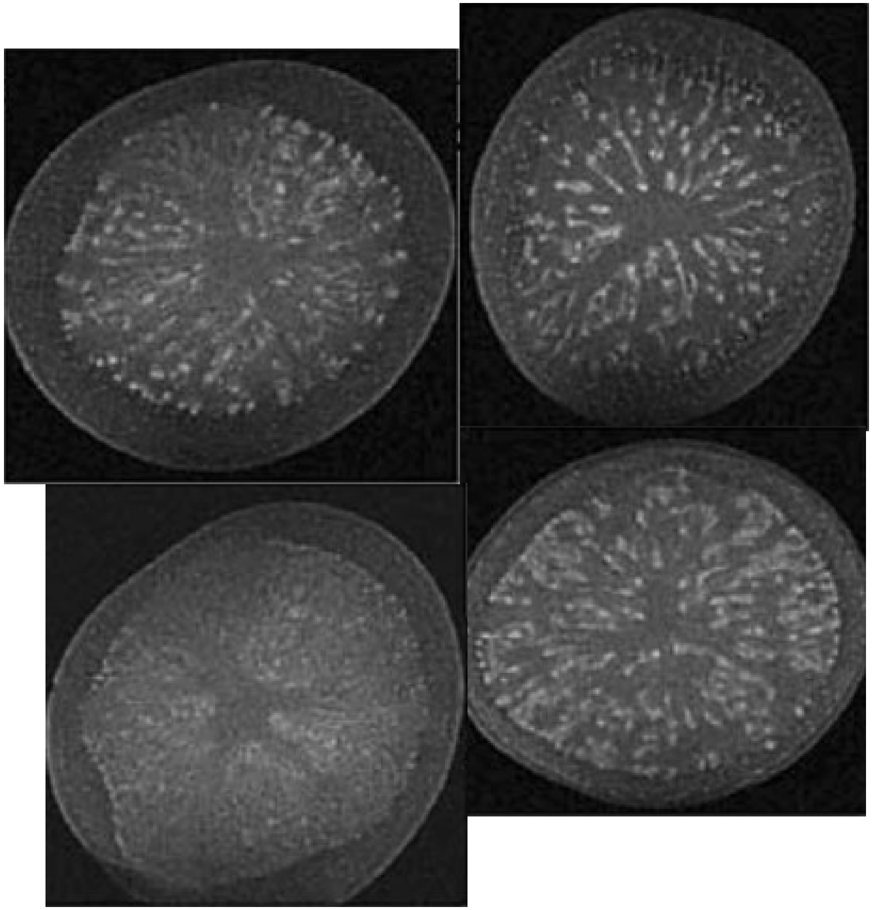
- MaZda/qmazda
- Vesselknife
- Ziarna (Grains)
- ParticlesWizard

Potato varieties recognition

Input
- MRI cross-sections of potatoes

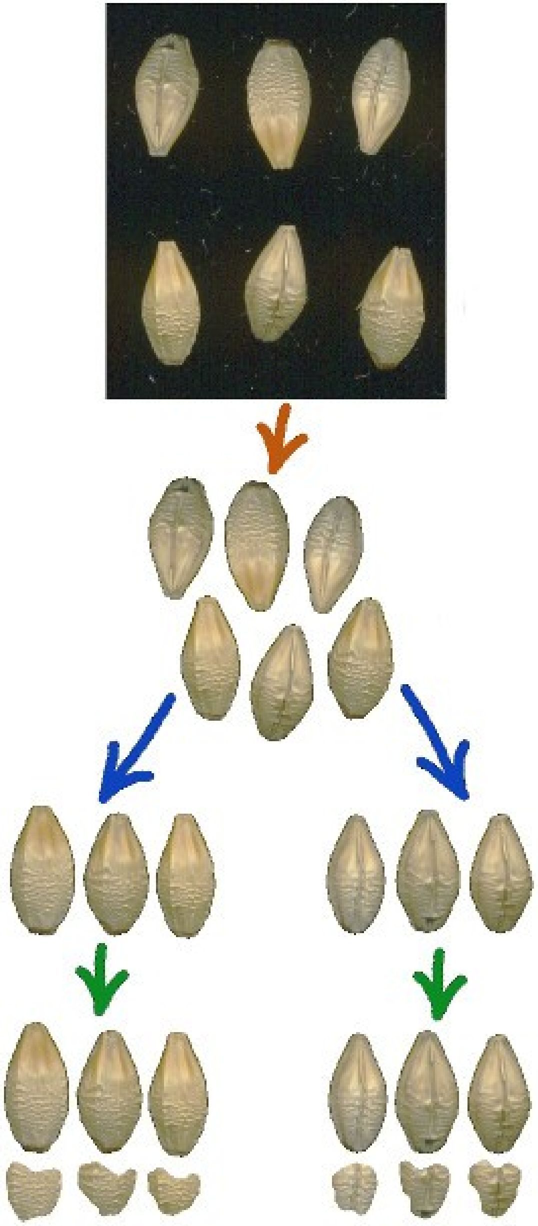
Methods
- Texture feature computation
- Discriminant analysis

Conclusions
- Potatoes as they grow develop directive, radial texture (starch clusters)
- Texture analysis enables discrimination of potato varieties



Thybo, Anette K., et al. "Prediction of sensory texture quality attributes of cooked potatoes by NMR-imaging (MRI) of raw potatoes in combination with different image analysis methods." *Journal of Food Engineering* 61.1 (2004): 91-100.

Barley variety recognition



Goal
- Selection of barley appropriate for malting

Input
- Visual images of barley grains

Methods
- Shape and image gradient analysis
- Orientation estimation
- Color and texture features computation
- Discriminant analysis

Conclusions
- Ventral and dorsal sides features are complementary
- Shape, color and texture analysis enable discrimination of varieties

Szczypiński, Piotr M., and Piotr Zapotoczny. "Computer vision algorithm for barley kernel identification, orientation estimation and surface structure assessment." Computers and electronics in agriculture 87 (2012): 32-38.

Szczypiński, Piotr M., Artur Klepaczko, and Piotr Zapotoczny. "Identifying barley varieties by computer vision." Computers and Electronics in Agriculture 110 (2015): 1-8.

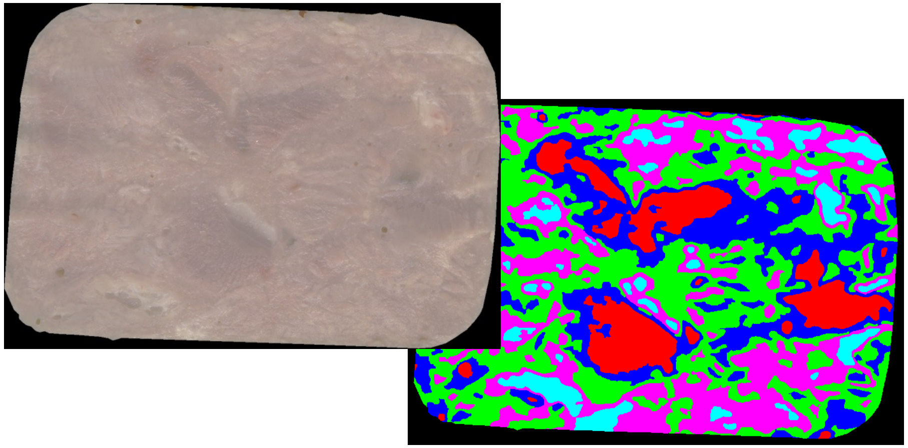
Cold meats quality evaluation

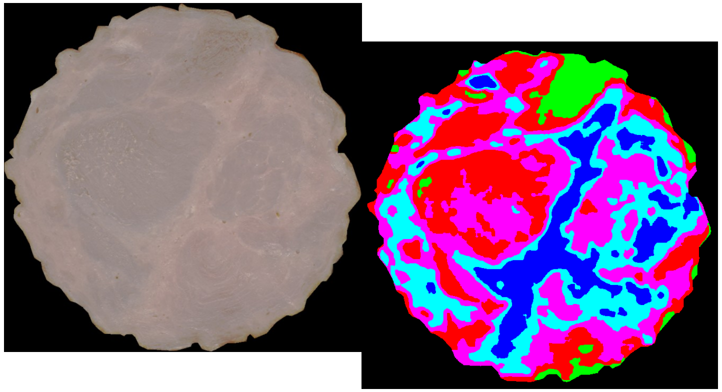
Goal
- To estimate proportions of ingredients

Input
- Visual and multispectral images of cold meats slices

Methods
- Texture and color feature maps computation
- Image segmentation (supervised and unsupervised)

Conclusions
- Texture and color enables segmentation of roughly grinded meats
- Selected texture and color features correlate with mechanical and chemical quality measures





Zapotoczny, Piotr, Piotr M. Szczypiński, and Tomasz Daszkiewicz. "Evaluation of the quality of cold meats by computer-assisted image analysis." *LWT-Food Science and Technology* 67 (2016): 37-49.

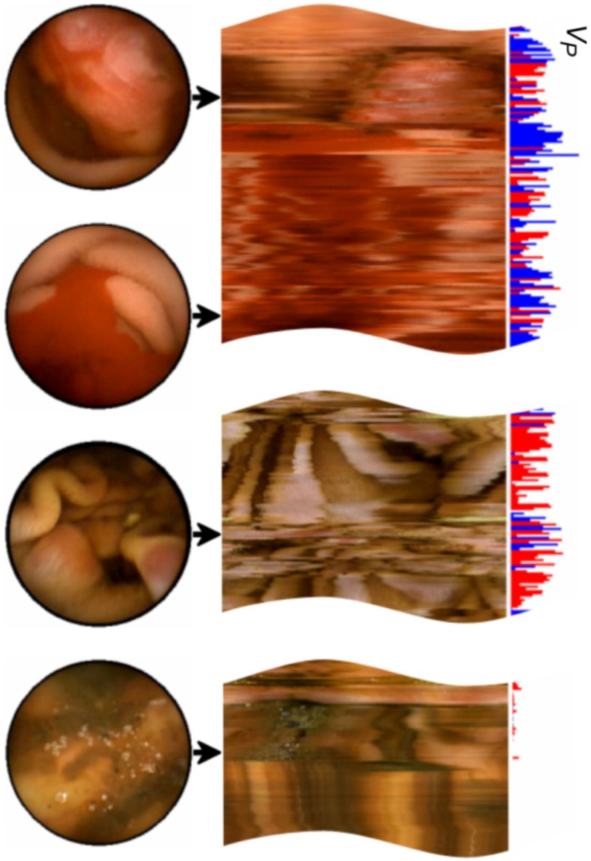
Endoscopy diagnosis support (NIST)

Goal
- Represent the gastrointestinal tract as a 2D map

Input
- Video from wireless capsule endoscope

Methods
- Capsule’s egomotion analysis by deformable model and optical flow
- Synthesis of small intestine internal surface image (map)

Conclusions
- Maps enable quick identification of large abnormalities and froth
- Using a map results in higher rates of abnormality detection



Szczypiński, Piotr M., et al. "A model of deformable rings for interpretation of wireless capsule endoscopic videos." *Medical Image Analysis* 13.2 (2009): 312-324.

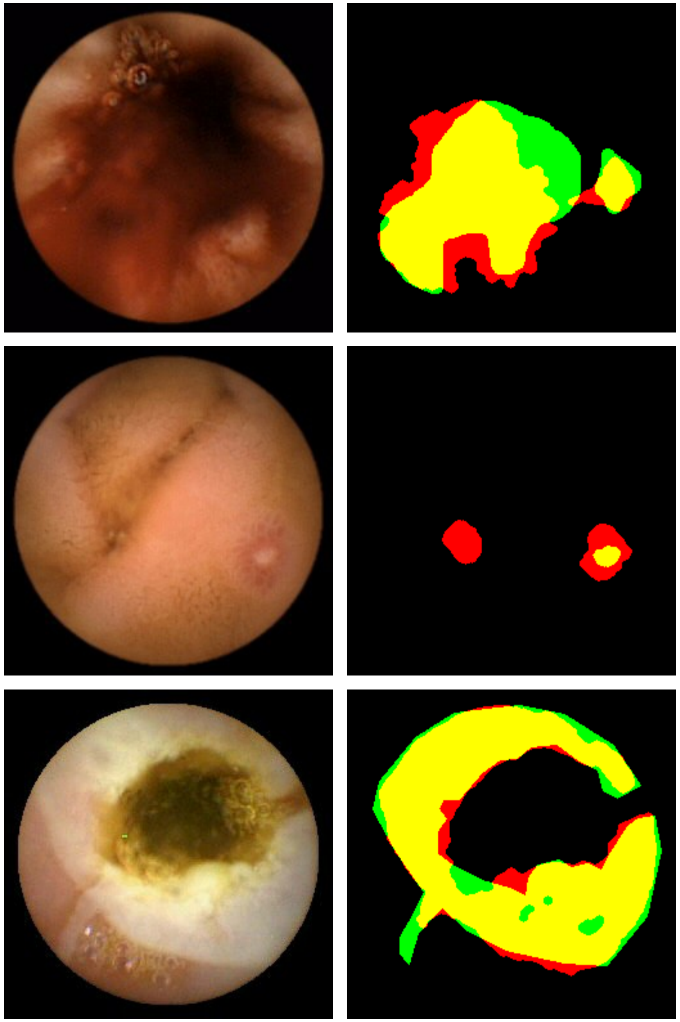
Endoscopy diagnosis support (LUT)

Goal
- Automatize detection and quantification of abnormalities (bleedings, ulcers, polyps, etc.)

Input:
- Video from wireless capsule endoscope

Methods:
- Texture and color analysis
- Discriminant analysis (supervised)
- Image segmentation

Conclusions:
- Texture and color features enable detection of abnormalities
- Texture and color based segmentation enables quantification of abnormality



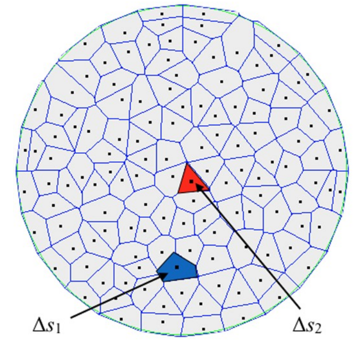
Szczypiński, Piotr, et al. "Texture and color based image segmentation and pathology detection in capsule endoscopy videos." Computer methods and programs in biomedicine 113.1 (2014): 396-411.

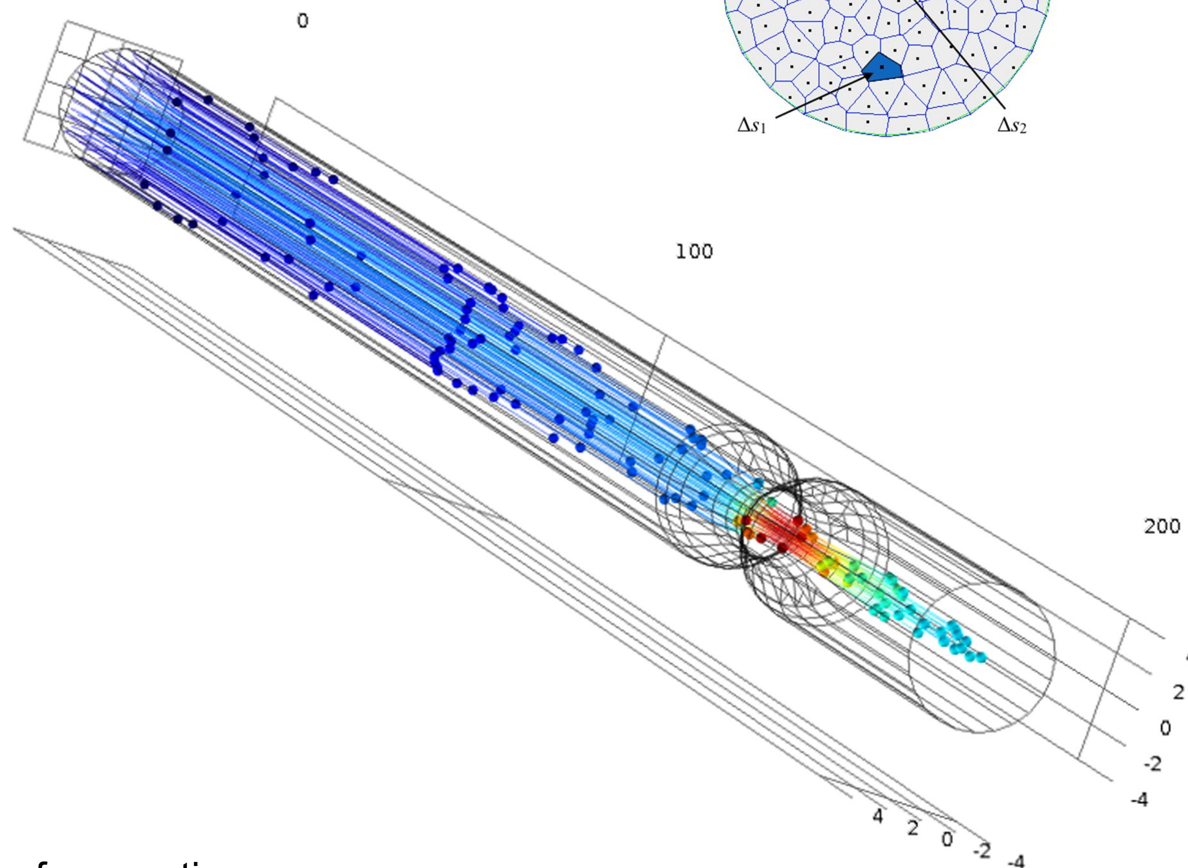
MR angiography simulation

Goal
- To simulate dynamic effects in MRA (Magnetic resonance angiography)
- Not to work to hard

Method
- 3D modeling
- Blood flow simulation (COMSOL)
- Particle tracking
- TOF-MOTSA effect simulation (modified SIMRI)

Results
- Reusability of flow simulation
- Solving problem of digital diffusion





Klepaczko, Artur, et al. "Computer simulation of magnetic resonance angiography imaging: model description and validation." PloS one 9.4 (2014)

Vessel tree modeling

Goal

- To build realistic models for MRA simulations

Input

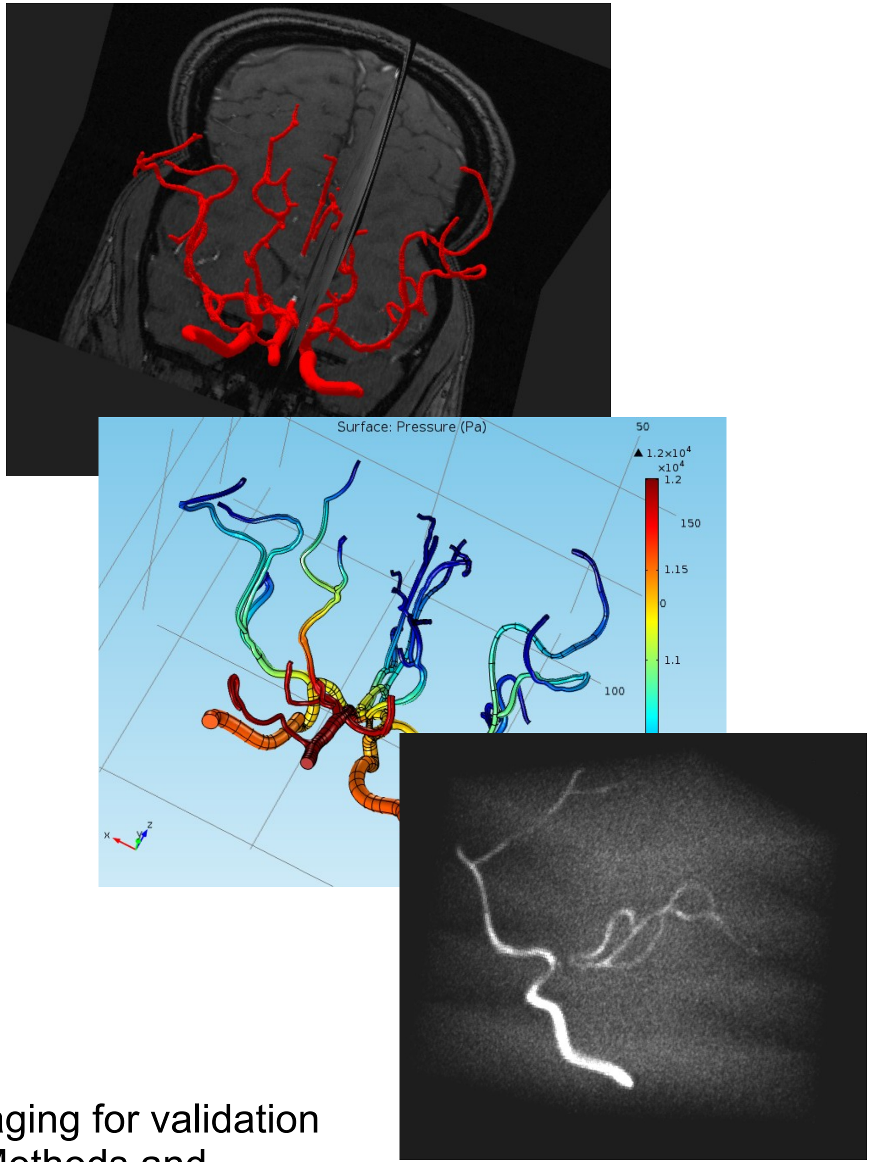
- TOF-MOTSA images
  (Time of Flight – Multiple Overlapping
  Thin Slab Acquisition)

Method

- Multiscale vesselness function based segmentation
- Skeletonization and centerline tracking
- Diameter estimation (original algorithm)
- Surface smoothing (deformable models)

Results

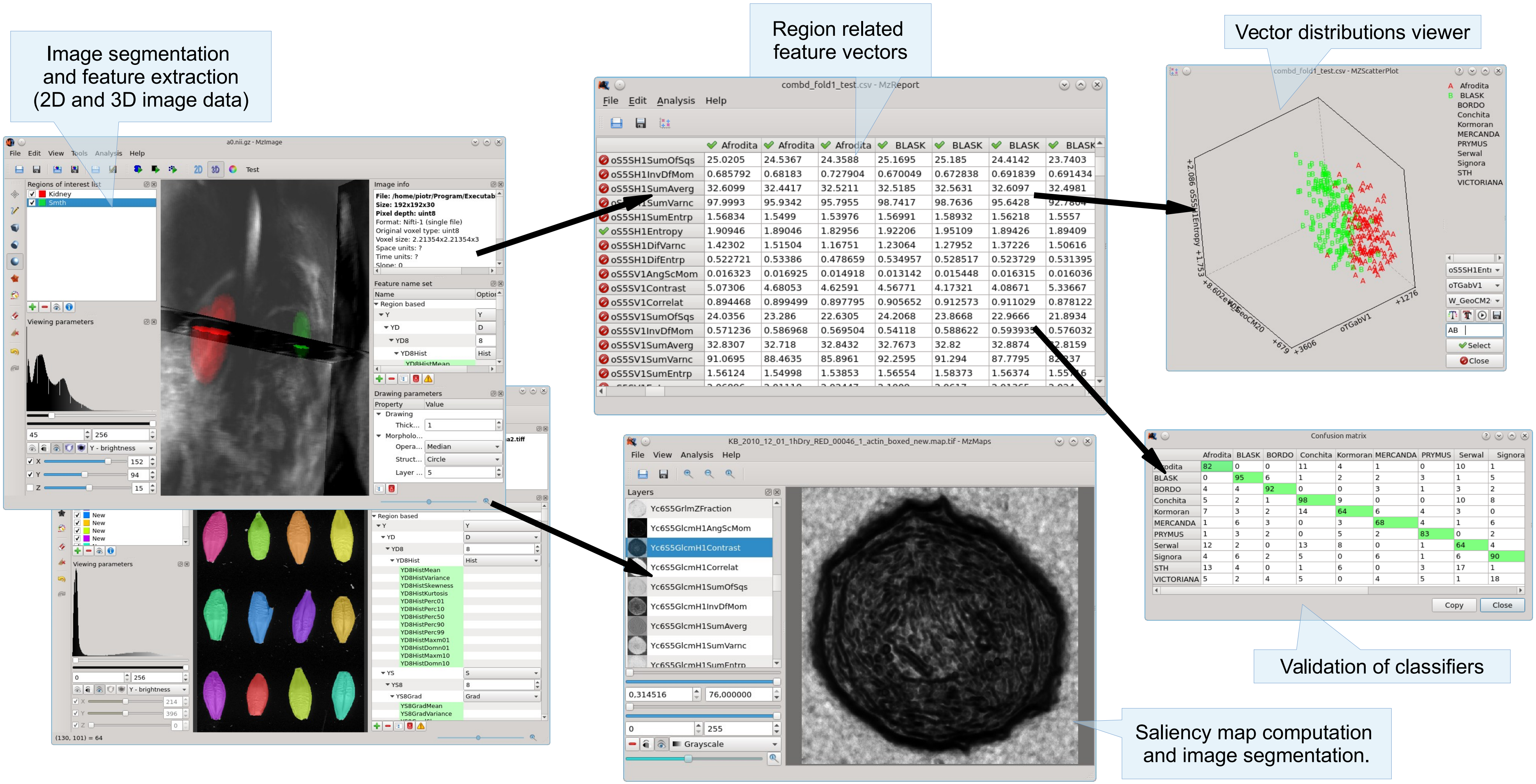
- Method for modeling of vessel structures with smooth walls
- Simulation results in internal carotid arteries



Klepaczko, Artur, et al. "Simulation of MR angiography imaging for validation of cerebral arteries segmentation algorithms." Computer Methods and Programs in Biomedicine (2016 under review)

Mazda/qmazda

gitlab.com/qmazda/qmazda.git

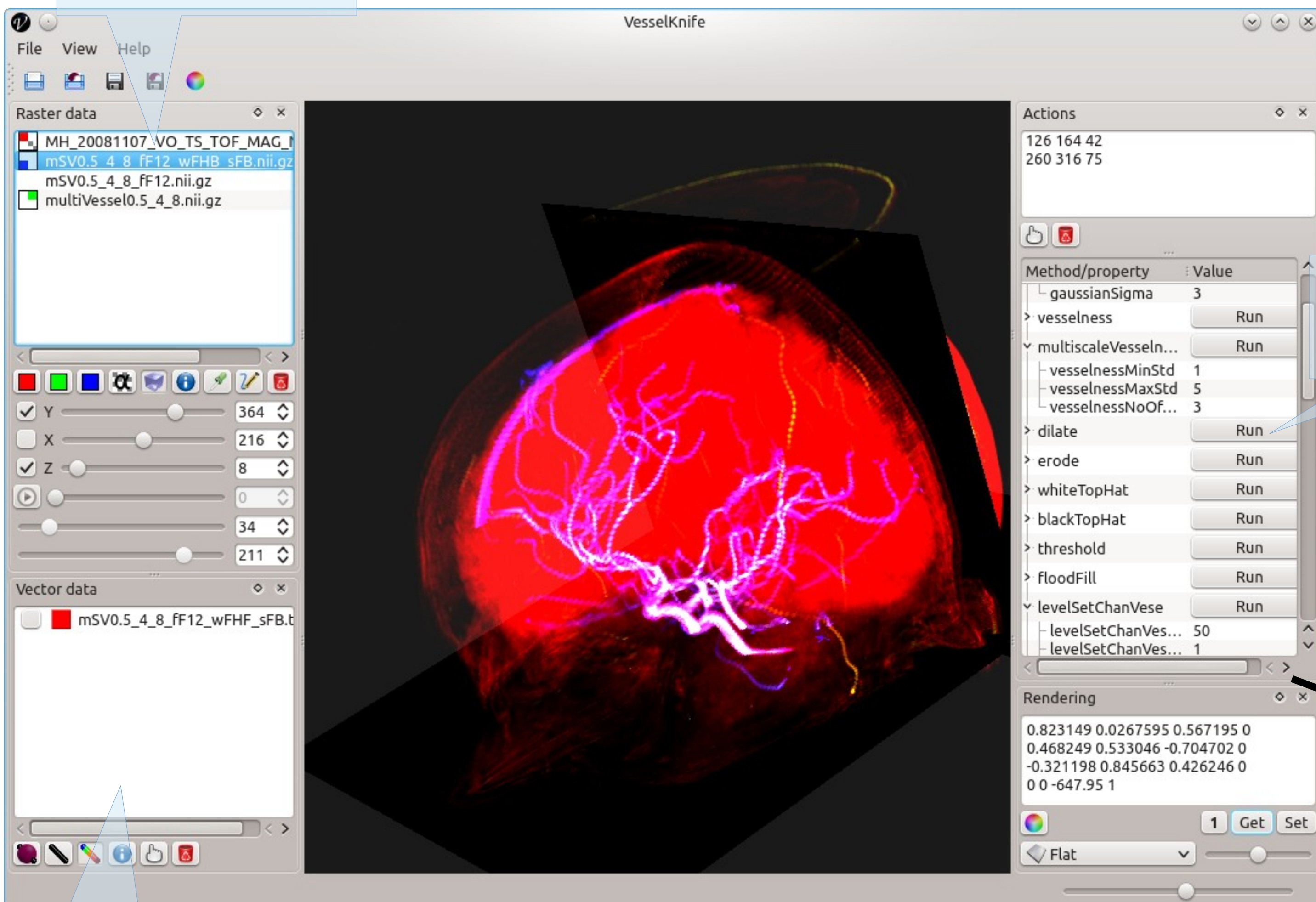


Szczypiński, Piotr M., et al. "MaZda—A software package for image texture analysis." Computer methods and programs in biomedicine 94.1 (2009): 66-76.

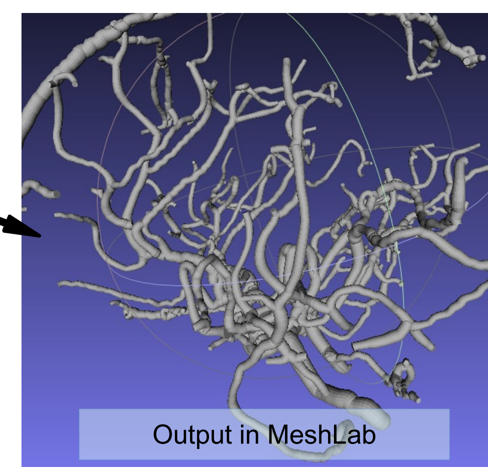
Vesselknife

gitlab.com/vesselknife/vesselknife.git

List of available images.
Visualization of images
in RGB channels



Interface for running
of image processing
algorithms.



List of 3D vector models

Work in progress

Fiber scaffold image segmentation

Input

- Confocal microscopy images of cells and fiber scaffold (separate channels)

Goal

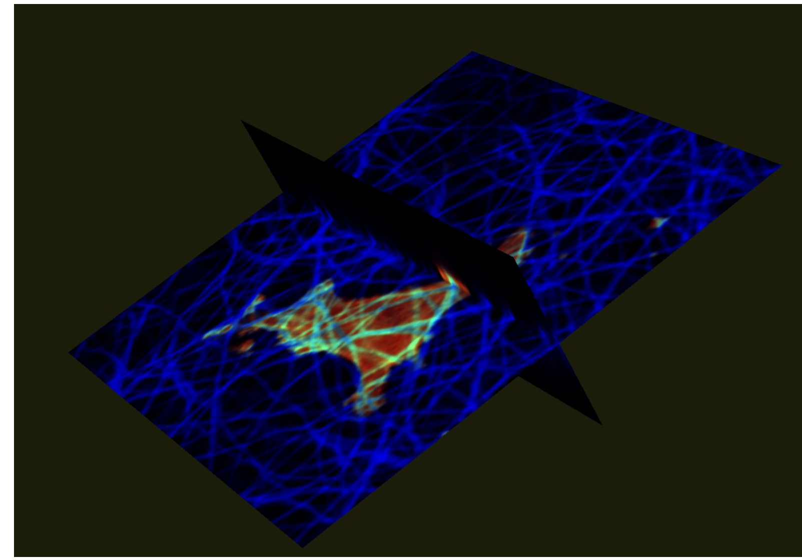
- To indicate attachment areas
- To segment and model cells and scaffold

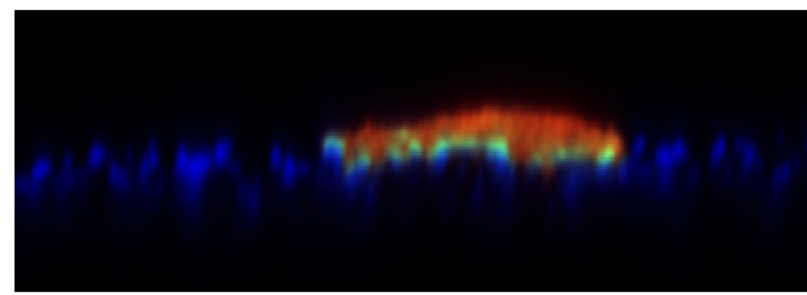
Problems

- Noise and optical distortions
- Problem with modeling fibers at crossings

Methods to apply

- Vesselness computation
- Image segmentation
- 3D modeling





Fiber scaffold channel

Cell fluorescence channel

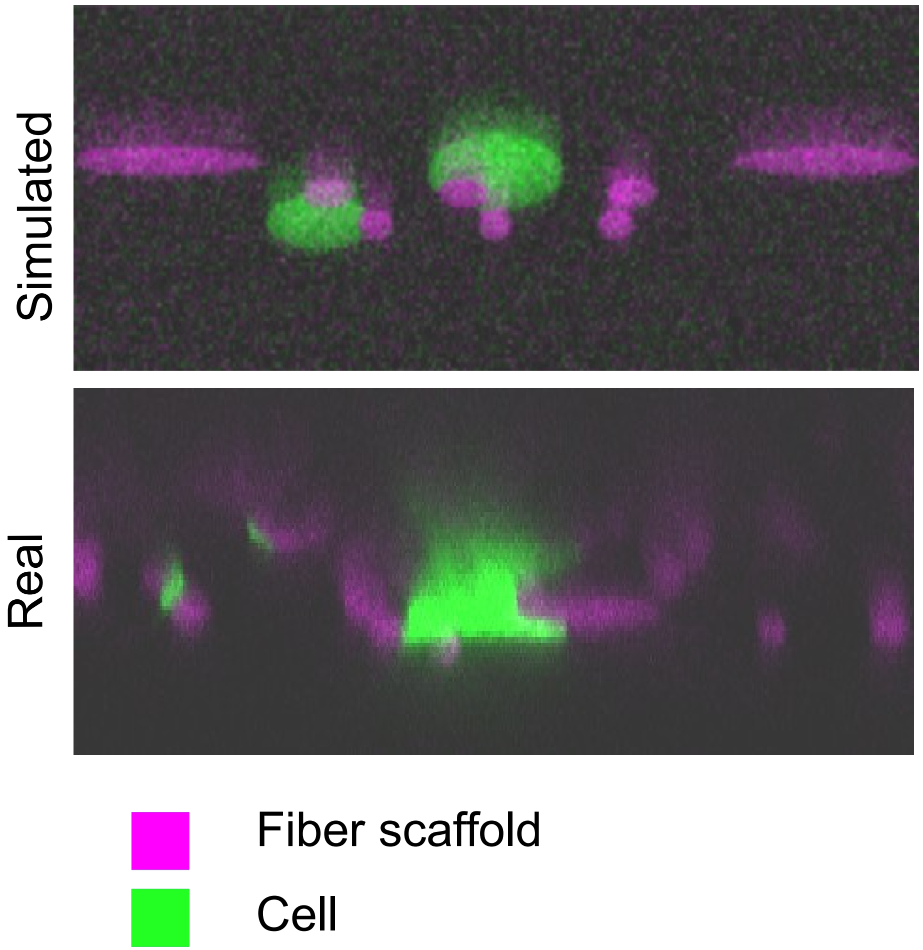
Attachment points

Work in progress
Simulations

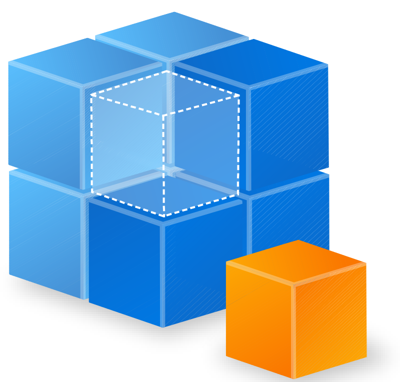
Input
- Scaffold image segmentation algorithms

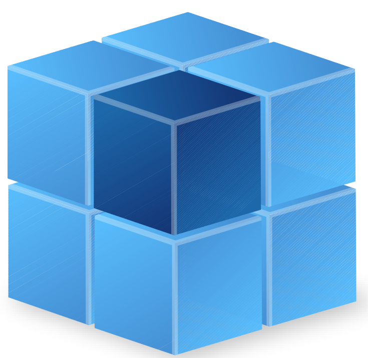
Goal
- To generate ground-truth data and realistic images for quantitative validation of developed algorithms

Methods to apply
- Simulation of image acquisition process
  - Cells' and scaffold geometries
  - Partial volume effect
  - Cross-bleeding
  - Optical distortions (PSF Point-spread function)
  - Noise



Summery and discussion





Piotr M. Szczypiński

Head of the Medical Electronics Division

Institute of Electronics, Lodz University of Technology

Wolczanska 211/215, 90-924 Lodz, Poland

tel.: +48 42631 2642

fax: +48 42 636 2238

e-mail: piotr.szczypinski@p.lodz.pl

http://www.eletel.p.lodz.pl/pms/