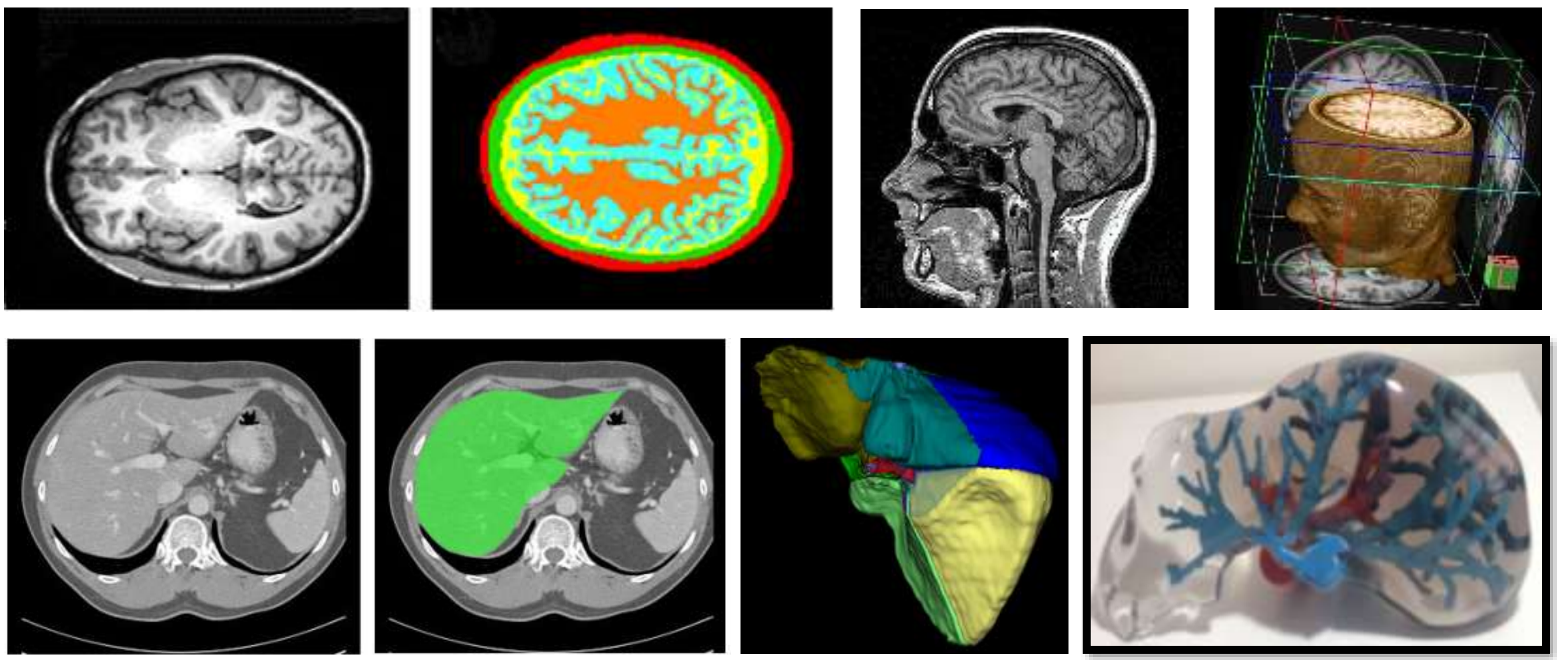
Medical Imaging Systems and **Segmentation of Organs in the Abdomen**

20/06/2019



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https://www.researchgate.net/profile/Ali_Kavur

MEDICAL IMAGING

Computed Tomography (CT)
Magnetic Resonance Imaging (MRI)

ORGAN SEGMENTATION

Segmentation of abdominal organs

SEGMENTATION METHODS

Classic approaches
Deep Learning based approaches
Alternative method: Classifier Ensemble

PERFORMANCE OF SEGMENTATION METHODS

Evaluation metrics
Segmentation challenges

QUESTIONS

BIO SKETCH


Estonia
Latvia
Lithuania
Belarus
Denmark
Ireland
United Kingdom
Netherlands
Belgium
Germany
Poland
Czech Republic
Ukraine
Slovakia
France
Switzerland
Austria
Moldova
Hungary
Slovenia
Croatia
Romania
rtugal
Spain
Italy
Serbia
Montenegro
Bulgaria
Georgia
Armenia
Azerbaija
Albania
Turkey
Greece
Izmir
Google Earth
US Dept of State Geographer
©2018 Google
Image Landsat / Copernicus
©2009 GeoBasis-DE/BKG
Malta
Syria
Cyprus
Lebanon
Iraq
Tunisia

BIO SKETCH

- İzmir is 3rd biggest city in Turkey
- Population: ~4 Million
- 6 state universities, 4 private universities



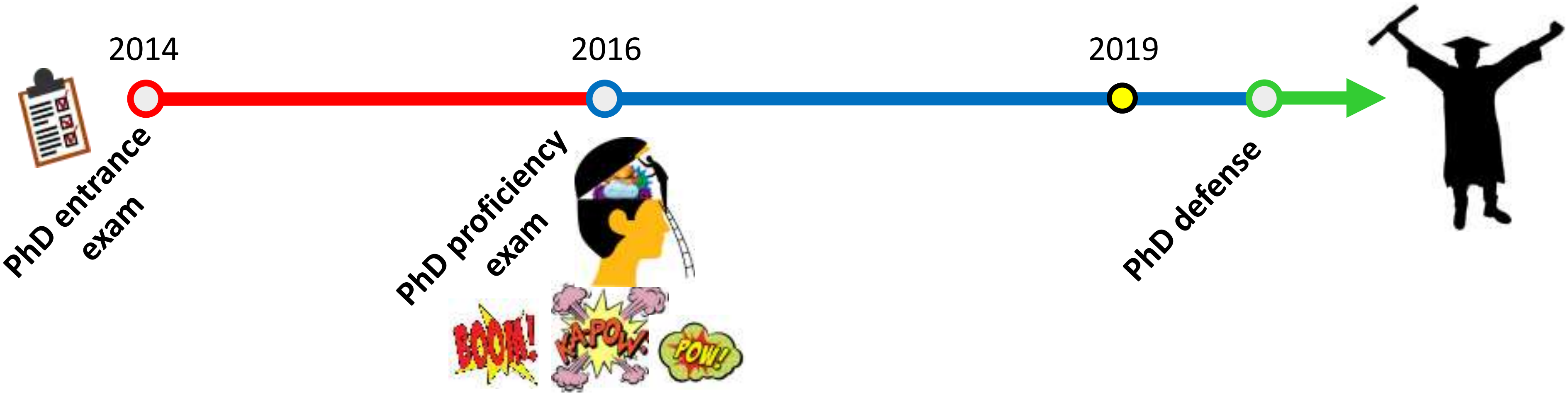



BIO SKETCH

- <u>BSc:</u> Izmir Institute of Technology (IZTECH) (Electronics and Communication Engineering)
- <u>MSc:</u> Dokuz Eylul University, (DEU) (Electrical Electronic Engineering)
- <u>PhD:</u> Dokuz Eylul University (DEU), Izmir (Electrical Electronic Engineering)

  Thesis: “Machine Learning Based Fusion of Different Segmentation Techniques for Liver Visualization for Enhanced Accuracy And Sensitivity”
- <u>Research of Interests:</u> Medical imaging systems, Medical image processing, Image Segmentation
- Academic Visitor of Prof. Kuncheva

PhD Education in Turkey



BIO SKETCH

Medical Image Processing at DEU

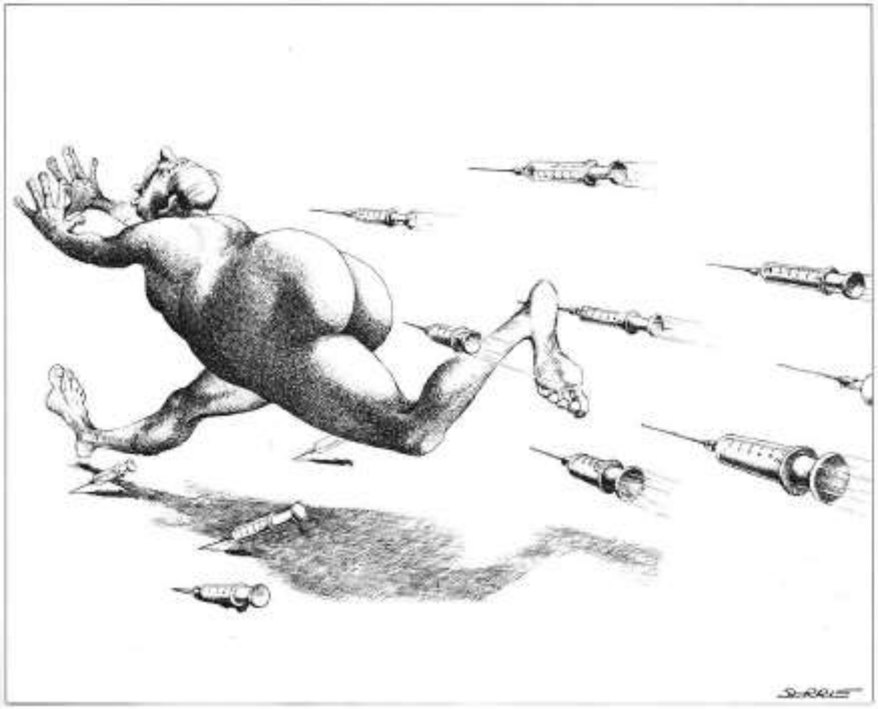
- Faculty of Engineering
  - Electrical Electronic Engineering
    - Medical Image Processing

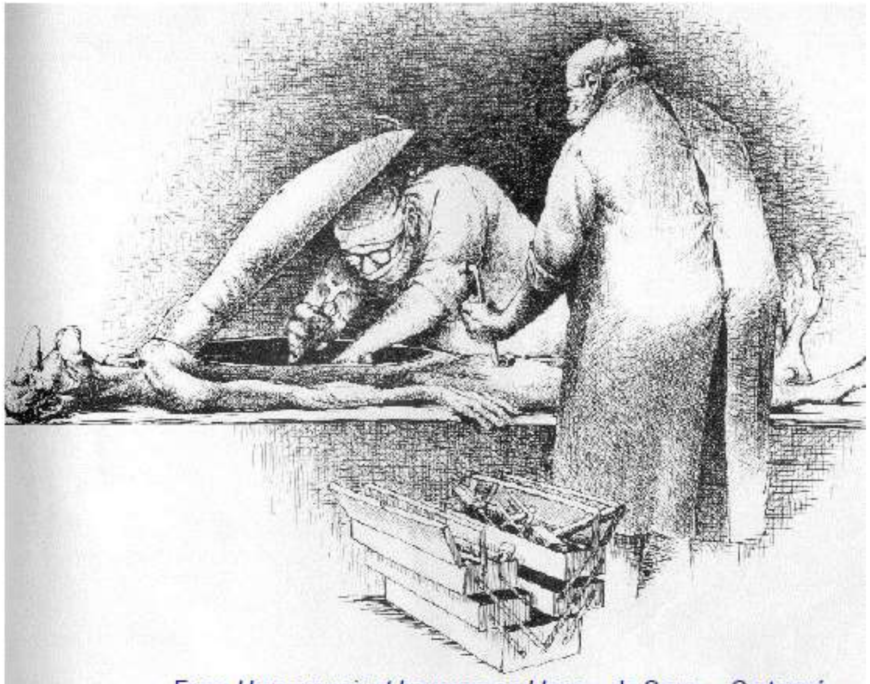
- Faculty of Medicine
  - Radiology

MEDICAL IMAGING

- Physicians need some data to diagnose and determine treatment. Some of those:
  - Observing symptoms,
  - Examination of body signals (ECG, EEG, etc.),
  - Tests (blood, urine, etc.)
- However, these tests are sometimes inadequate for the diagnosis of the disease.

Physicians may need a biopsy or a direct look into the patient for further analysis before medical imaging systems.



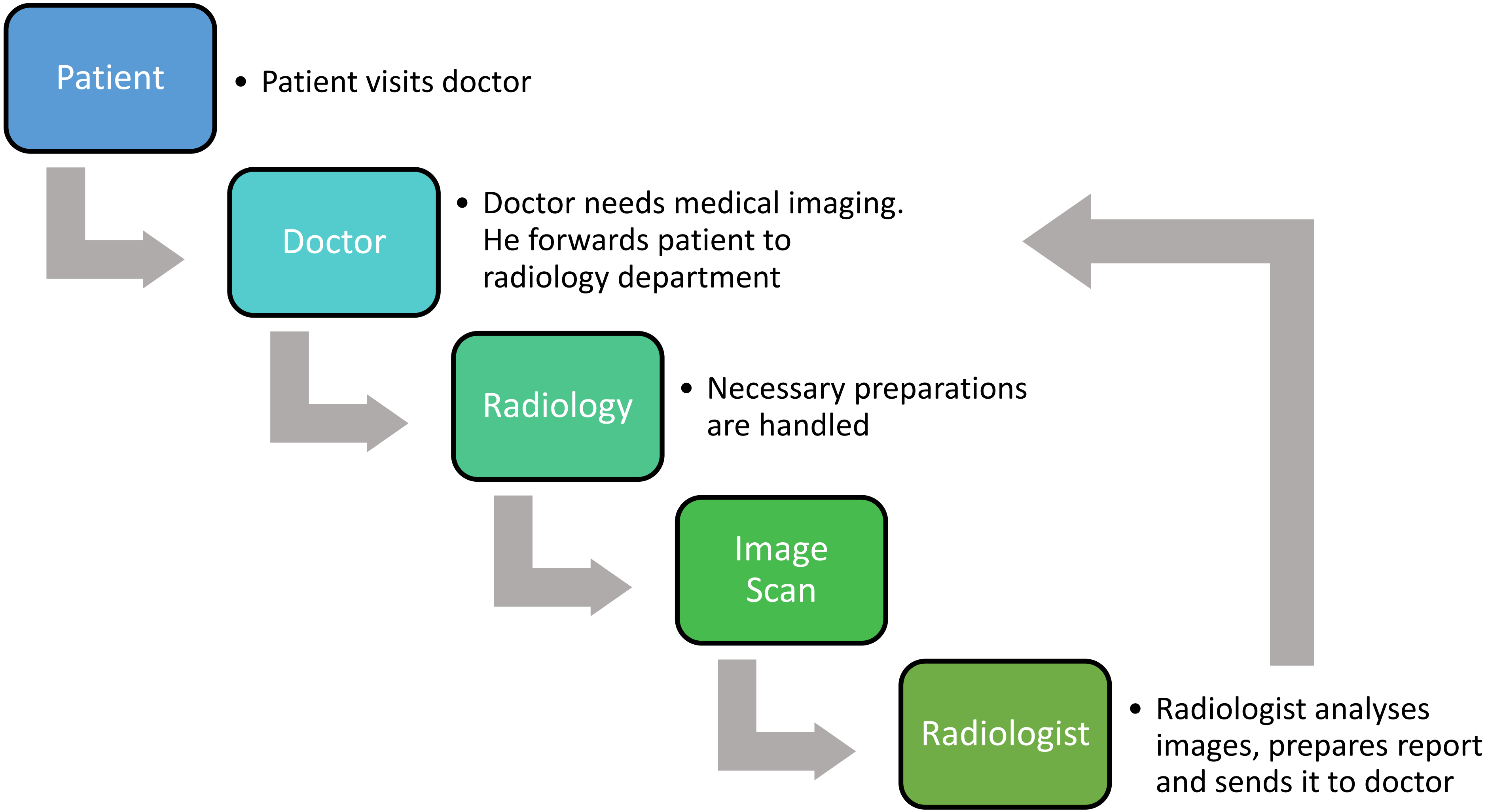


From *Humour noir et hommes en blanc* -- de Serre -- Cartonné

MEDICAL IMAGING

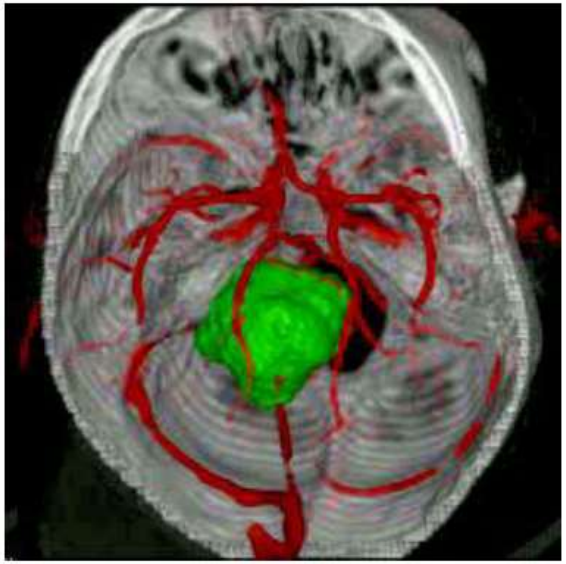
- Medical imaging systems make the internal structure of the human body visible through various methods.
- With medical imaging systems, physicians can perform <u>faster</u>, <u>painless</u> and <u>precise</u> analyzes. Therefore, medical image processing tools are frequently used.
- The branch of medicine that uses these images for medical diagnosis and treatment is called «Radiology».
- The doctors who specialize in this subject are called as «Radiologists».

MEDICAL IMAGING



MEDICAL IMAGING

Diagnosis



Surgery planning

Endoscopic Surgery

MEDICAL IMAGING

Some widely used medical imaging systems:

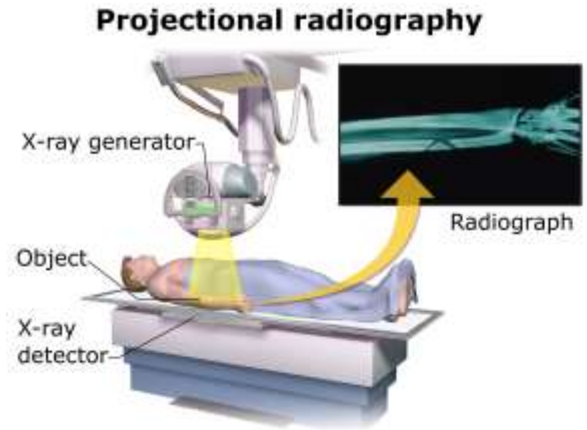
- Ultrasound
- Endoscopy
- X-ray
- Tomography
  - X-ray computed tomography (CT)
  - Positron emission tomography (PET)
  - Magnetic resonance imaging (MRI)
  - Optical coherence tomography (OCT)

MEDICAL IMAGING

X-ray

- X-ray imaging was invented by Wilhelm Conrad Röntgen at Würzburg University in Germany. (November 8th of 1895)
- It works on the principle of passing X-rays through the patient.
- The radiation from the body is dropped onto a film or sensor.
- It is fast and economical.
- It is risky because it contains radiation.

Wilhelm Röntgen



X-ray imaging system

First medical X-ray image. Röngen’s wife's hand.

A modern X-ray image

Tomography

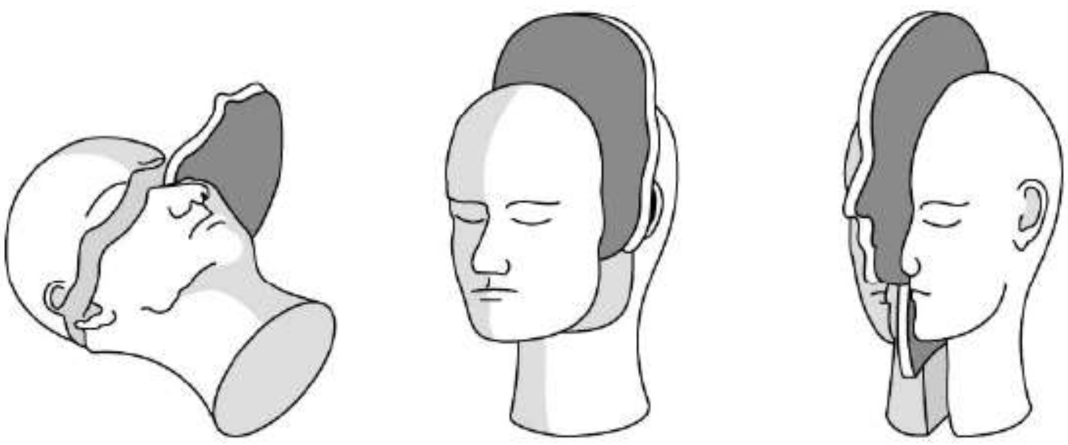
- The word *tomography* is derived from Greek words:

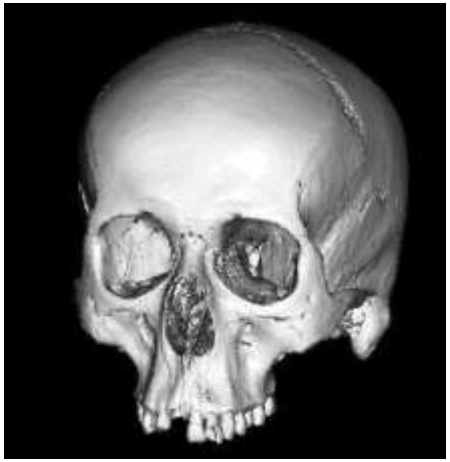
  Tomos: "slice, section"

  Graphō: "to write"

  Tomography: Slice writing

- Tomography is a technique for displaying a representation of a cross section through a solid object.

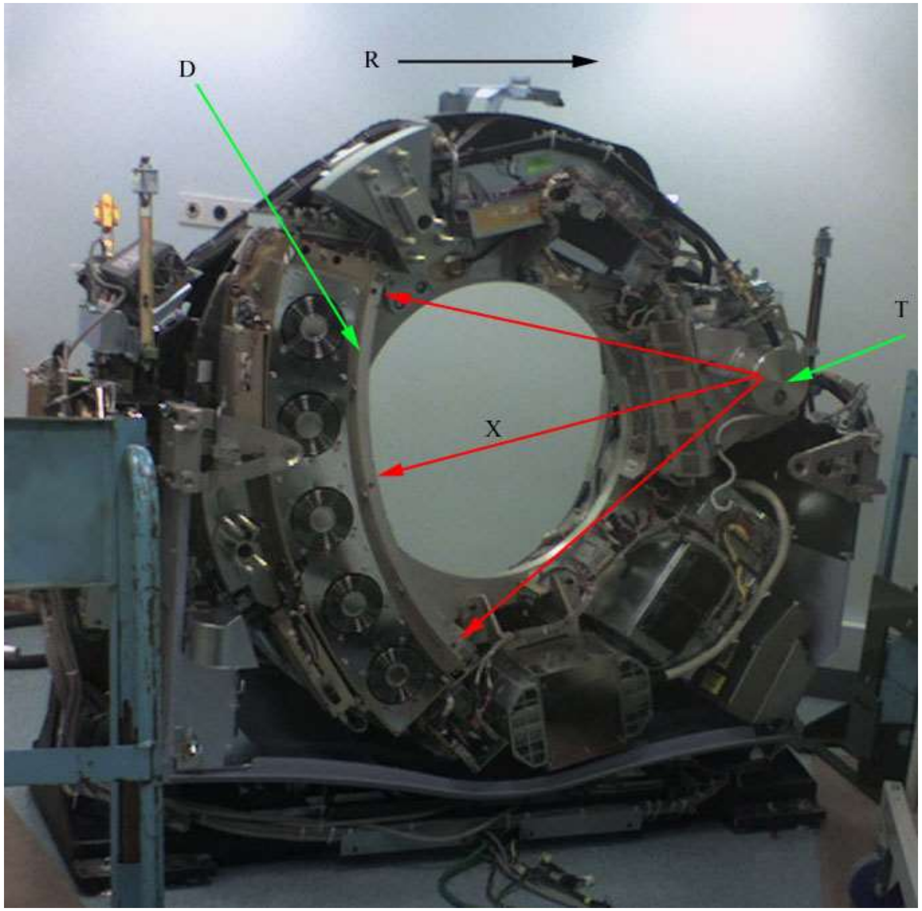




MEDICAL IMAGING

Computed Tomography (CT)

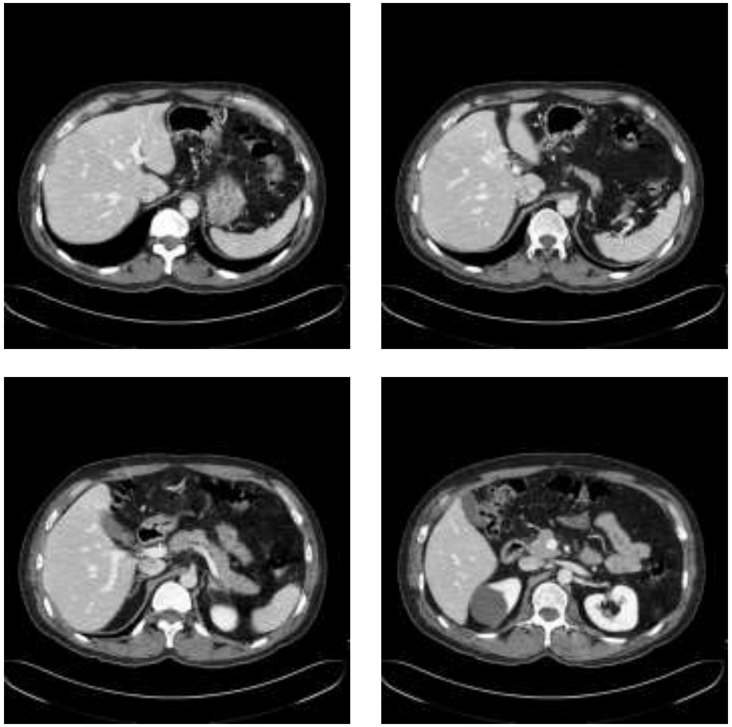
- CT uses several X-ray measurements taken from different angles
- CT combines different X-rays to produce cross-sectional (tomographic) image.
- CT generates virtual slices of specific areas of a scanned object.

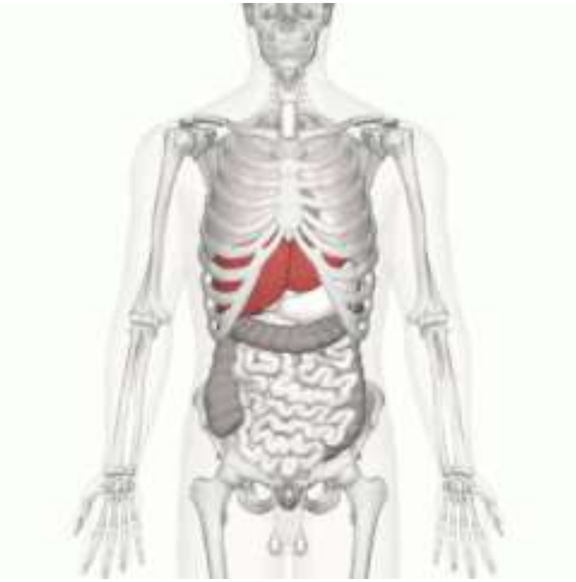


CT scanner without cover
T: X-ray tube
D: X-ray detectors
X: X-ray beam
R: Gantry rotation
Source: https://en.wikipedia.org/wiki/CT_scan

Computed Tomography (CT)

- Physicians can examine images in 3 dimensional or cross-sectional

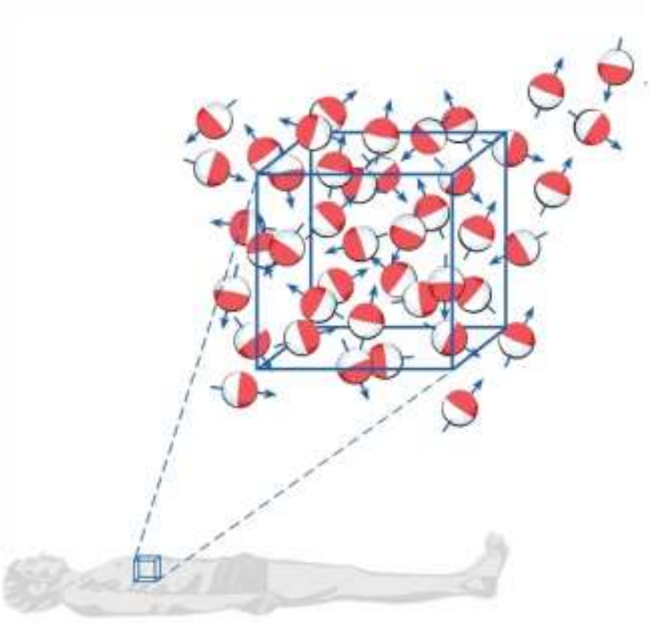




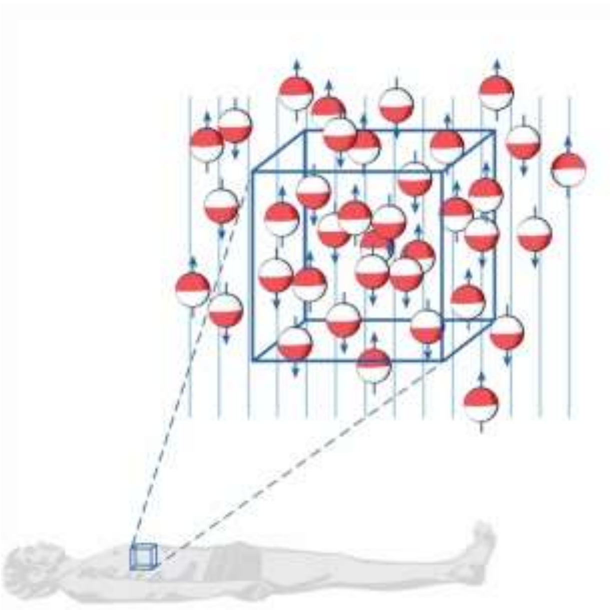
Source: https://en.wikipedia.org/wiki/Liver

Magnetic Resonance Imaging (MRI)

- The image is created using magnetic dipoles of atoms.
- The patient is placed in a very high **constant** magnetic field (M0) and the magnetic dipoles of all atoms are aligned.



Magnetic dipoles of atoms have different movements



Magnetic dipoles of atoms are aligned under high magnetic field.

Magnetic Resonance Imaging (MRI)

- How much **constant** magnetic field(M0) does a typical MRI have?

0.5-0.6 Gauss

3 Tesla

Magnetic Resonance Imaging (MRI)

- How much **constant** magnetic field(M0) has a typical MRI?

0.5-0.6 Gauss

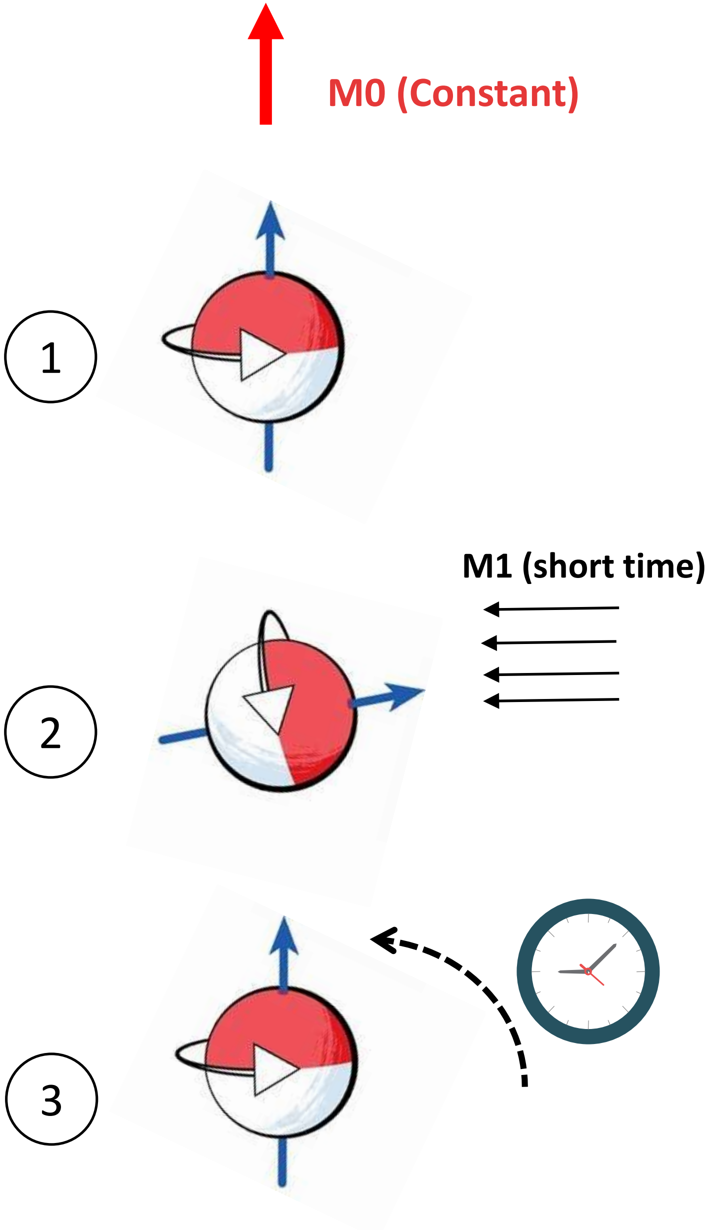
3 Tesla = 30000 Gauss

1 Tesla = 10 000 Gauss

MEDICAL IMAGING

Magnetic Resonance Imaging (MRI)

1) **Another temporary magnetic field (M1) ,** in a different direction is added to the constant magnetic field (M0).
2) M1 excites the atoms in the body for a short time and inclines their magnetic dipoles.
3) M1 is turned off. Then, the magnetic dipoles of the excited atoms are restored (relaxed). The elapsed time between the two positions of the magnetic dipoles is measured and imaging is performed.



Magnetic Resonance Imaging (MRI)

- Atoms/Molecules in different tissues have different excitation-relaxation times.
- This fact is used to generate images from different tissues which have contrast.

CT and MRI Comparison

- CT generates high contrasted images from hard tissues such as bones.
- CT can be risky because it uses X-ray which can ionize the atoms.
- CT is more economic than MR.
- CT is very fast w.r.t MRI (30 seconds is enough for abdomen CT).

- MRI is safer than CT because it does not ionize the atoms.
- MRI creates a better image in soft tissues such as brain, cartilage, eye, and inflammation, where the hydrogen atoms prevail.
- MRI cannot be applied to people with metal objects (prosthesis, etc.).
- MRI is insufficient for imaging bone and other tissues containing calcium.
- MRI is slow (An abdomen MR may take 20-25 minutes).
- It is critical that the patient remains stationary during an MRI scan.
- MRI is expensive.

Difficulties of Medical Imaging

Classic art

Impressionism

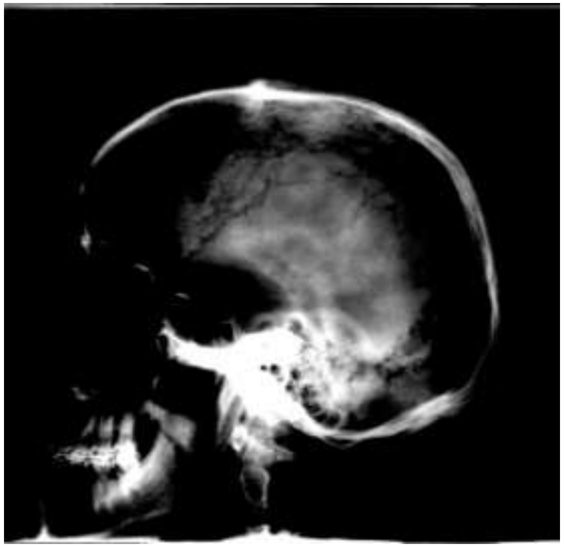
Difficulties of Medical Imaging

- Medical imaging has to be done in the fastest, safest and most economical way.
- Therefore, the resulting image quality may be poor and noisy.
- Improving these images, making them usable for physicians, analysing the information from the images are the main aims of medical image processing.
- The use of images can be vital, so medical image processing should be performed without errors.
- Light source is not used for medical imaging. Therefore, images are obtained in monochrome (colourless).

What is perfect?

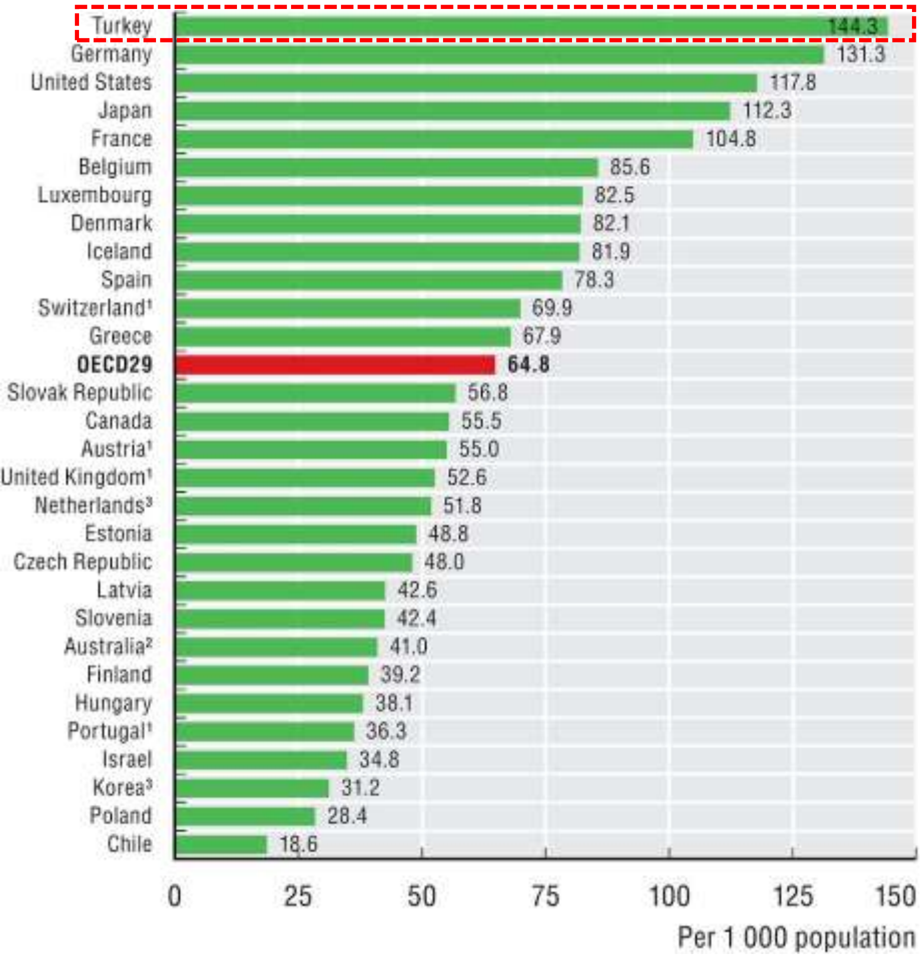
Which one is best?



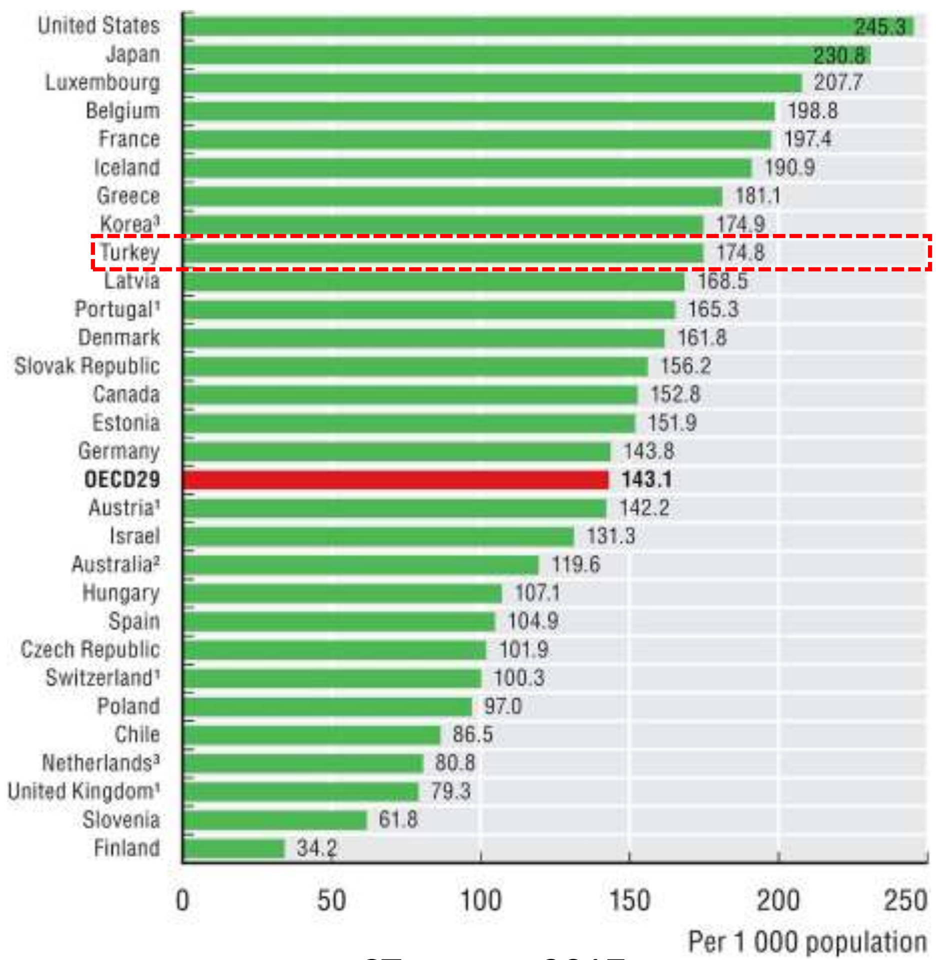


MEDICAL IMAGING

Medical Imaging Facts



MRI exams, 2017
(Total: 11 million MRI scans)

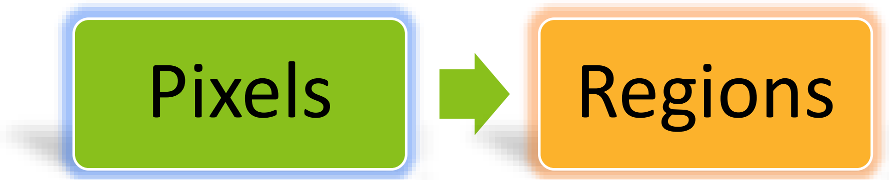


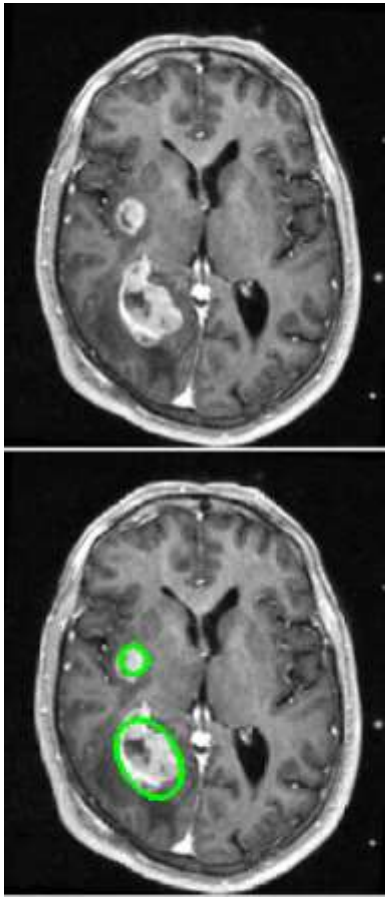
CT exams, 2017
(Total: 14.5 million CT scans)

Source: https://www.oecd-ilibrary.org/sites/health_glance-2017-61-en/index.html?itemId=/content/component/health_glance-2017-61-en

ORGAN SEGMENTATION

What is image segmentation?

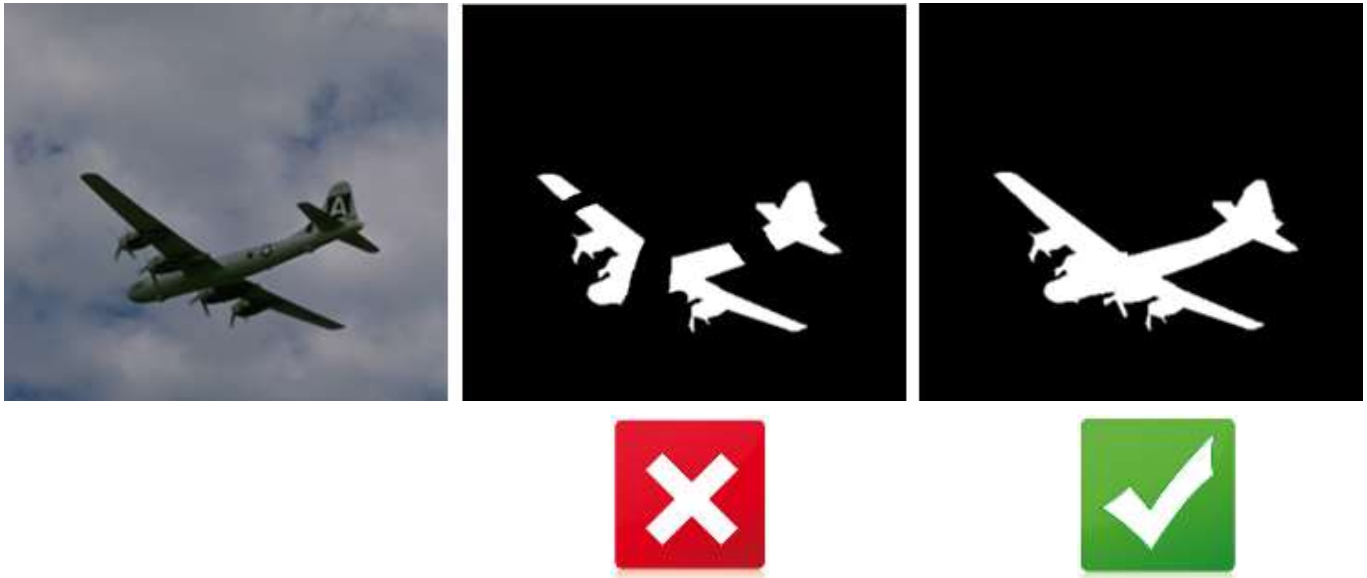




- Segmentation refers to the process of partitioning an image into multiple region(s) (sets of pixels). In other words, segmentation classifies voxels/pixels into objects or groups
- Image segmentation reduces pixel data to region-based information
- The segmentation is based on measurements taken from the image and might be grey level, color, texture, depth or motion.

What is NOT image segmentation?

- The purpose of image segmentation is to partition an image into **<u>meaningful</u>** regions with respect to a particular application



ORGAN SEGMENTATION

What is the need of image segmentation in general?

- Segmentation is typically the first step in object identification in an image.

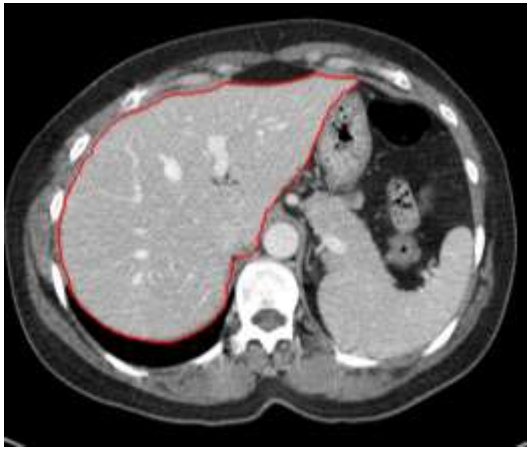
- The ultimate goal is to find meaning from an image whether it is to identify an object, understand interactions, etc.

- It may also be used in compression to compress different areas, segments of an image, at different compression qualities.

ORGAN SEGMENTATION

What is the need for image segmentation in medical imaging?

- In medical applications, it is a fundamental process in most systems that support:
  - ➢ Medical diagnosis,
  - ➢ Surgical planning,
  - ➢ Treatment planning



ORGAN SEGMENTATION

Patient

- Patient visits doctor

Doctor

- Doctor needs medical imaging. He forwards patient to radiology department

Radiology

- Necessary preparations are handled

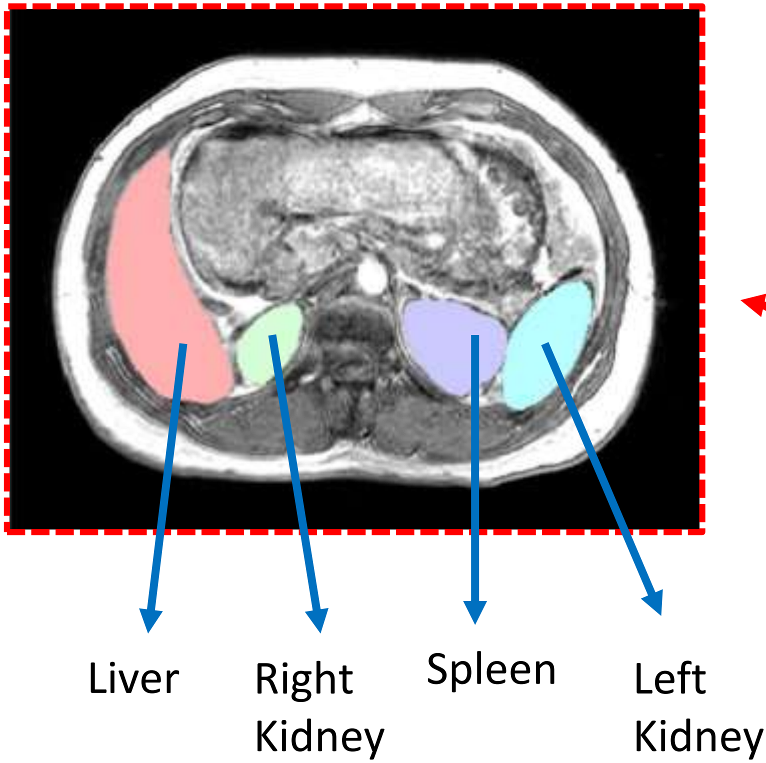
Image Scan

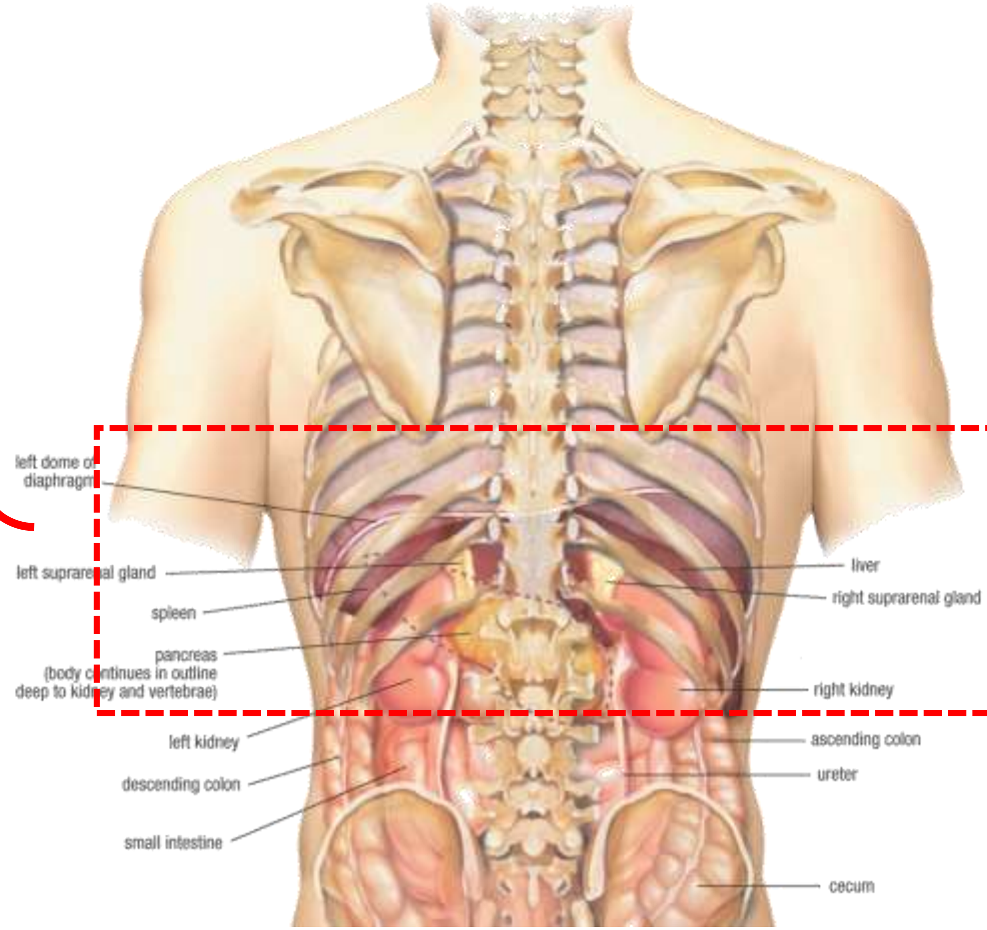
Radiologist

- Radiologist analyses images, prepares report and sends it to doctor

ORGAN SEGMENTATION

Segmentation of Organs in the Abdomen

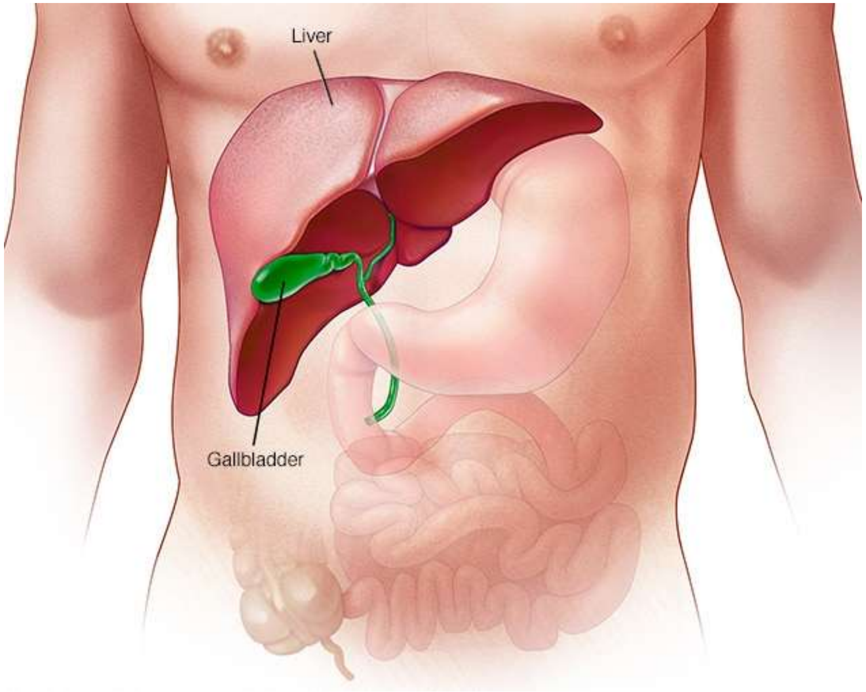




Segmentation of Organs in the Abdomen

Some Functions of the liver:

- Bile production and Secretion.
- Secretion of bilirubin, cholesterol, hormones, and drugs.
- Metabolism of fats, proteins, and carbohydrates.
- Enzyme activation.
- Storage of glycogen, vitamins, and minerals.
- Synthesis of plasma proteins, such as albumin, and clotting factors.



Hence, liver is one of the most scanned organ in the body.

SEGMENTATION METHODS

Segmentation Flowchart

Image → Preprocessing (If needed) → Segmentation → Post Processing (if needed)

Preprocessing (If needed):

- Filtering
- Denoising
- Feature extraction
- Resampling
- Cropping

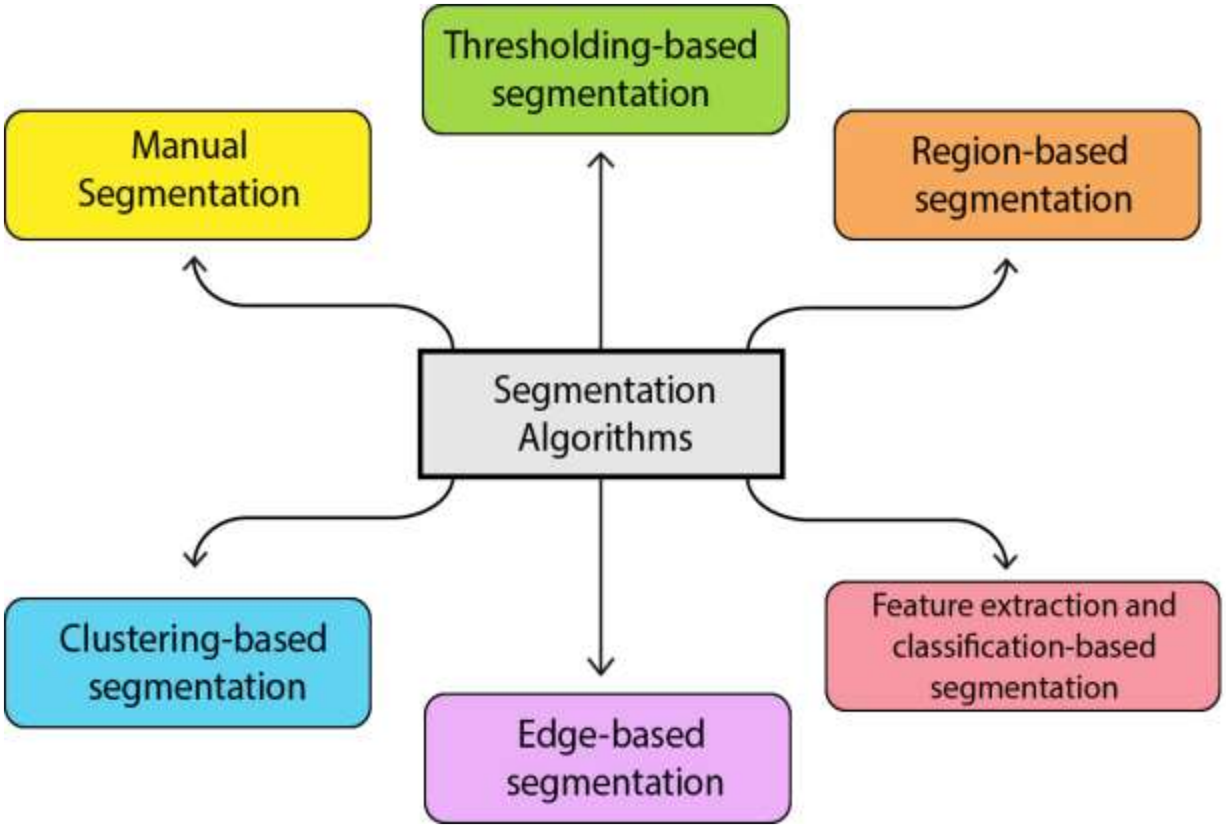
Post Processing (if needed):

- Filtering
- Smoothing
- Filling holes
- Erosion/Dilation

SEGMENTATION METHODS

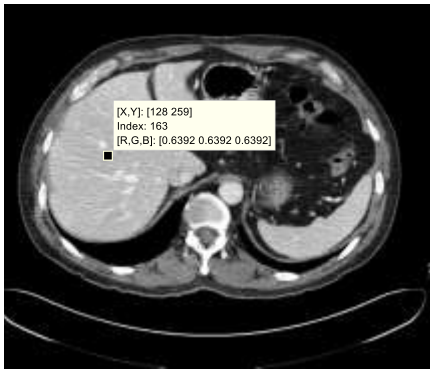
Classical Segmentation methods

There are manual, semi-automatic and automatic segmentation methods for medical image segmentation.

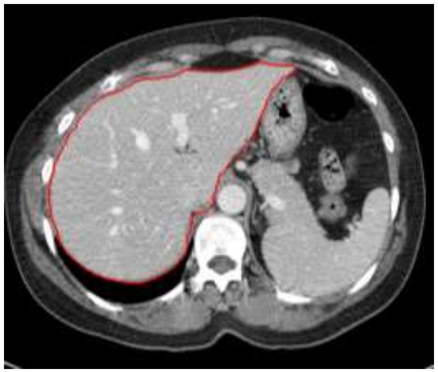


SEGMENTATION METHODS

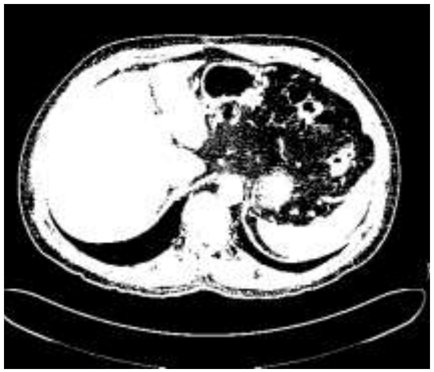
Classical Segmentation methods



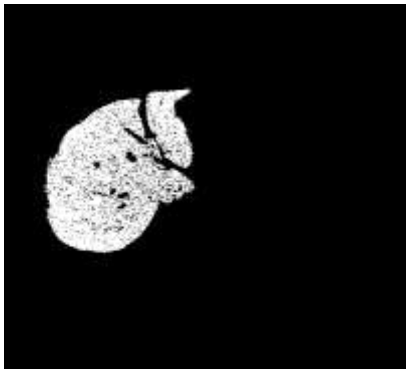
Source



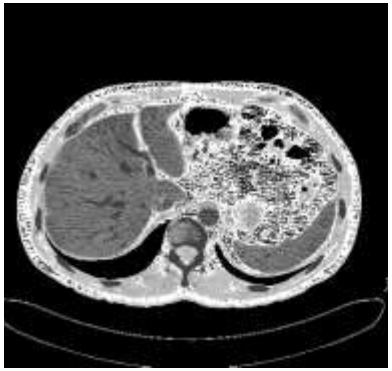
Manual



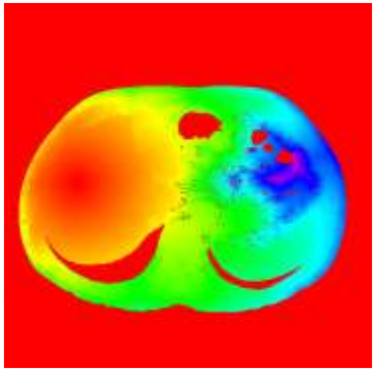
Thresholding



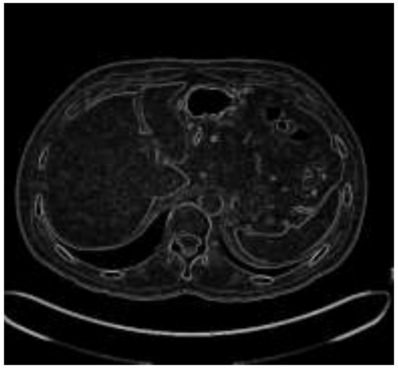
Region Growing



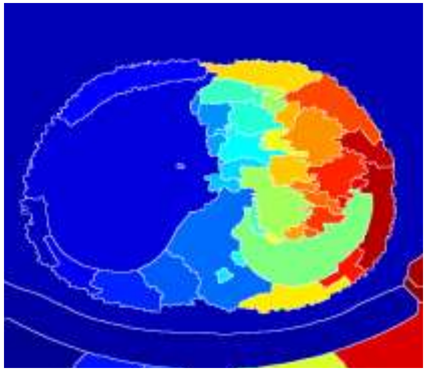
Clustering



Fast Marching



Edge detection



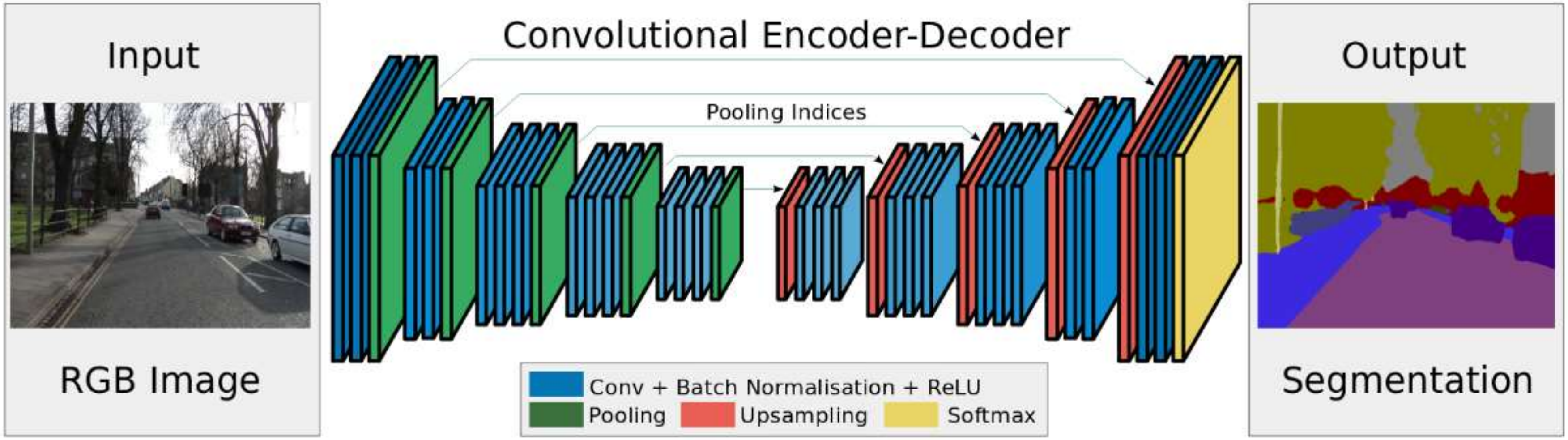
Watershed

SEGMENTATION METHODS

Deep Learning

"Deep learning is a class of machine learning algorithms that use <u>multiple layers</u> to progressively extract <u>higher level features</u> from raw input. For example, in image processing, lower layers may identify edges, while higher layer may identify human-meaningful items such as digits/letters or faces."

Source: https://en.wikipedia.org/wiki/Deep_learning

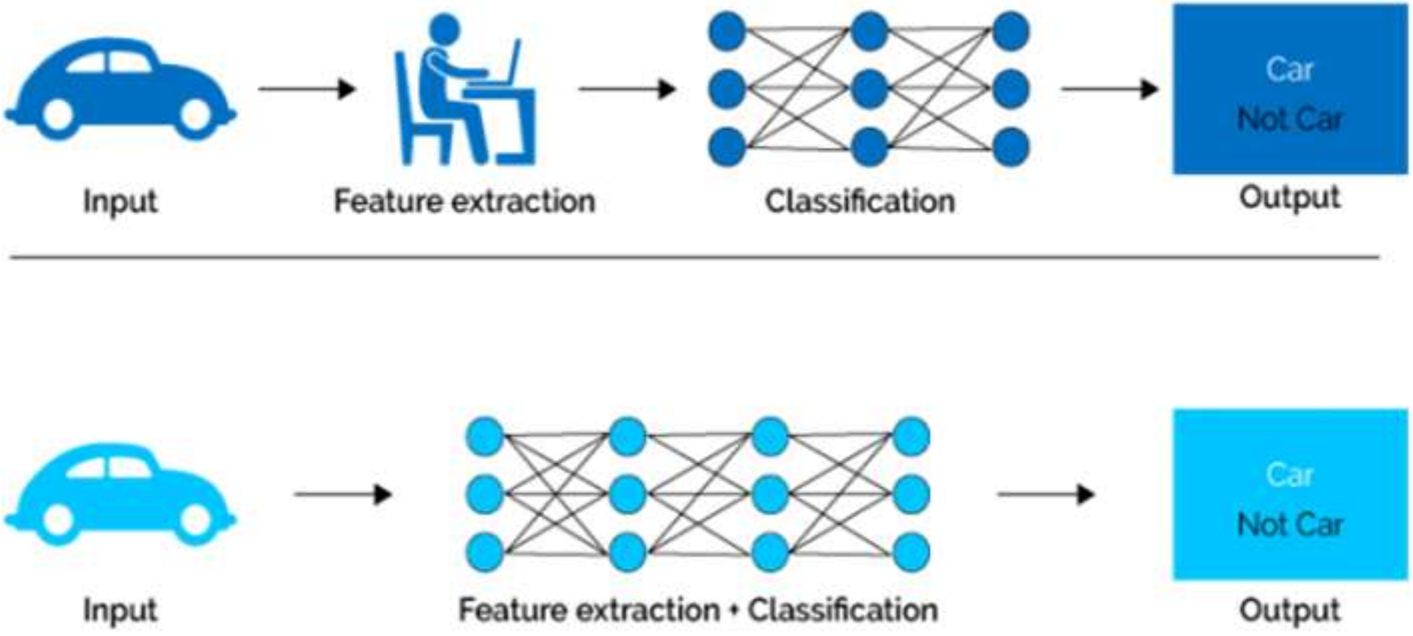


Source: A Review on Deep Learning TechniquesApplied to Semantic Segmentation
https://arxiv.org/pdf/1704.06857.pdf

SEGMENTATION METHODS

Deep Learning

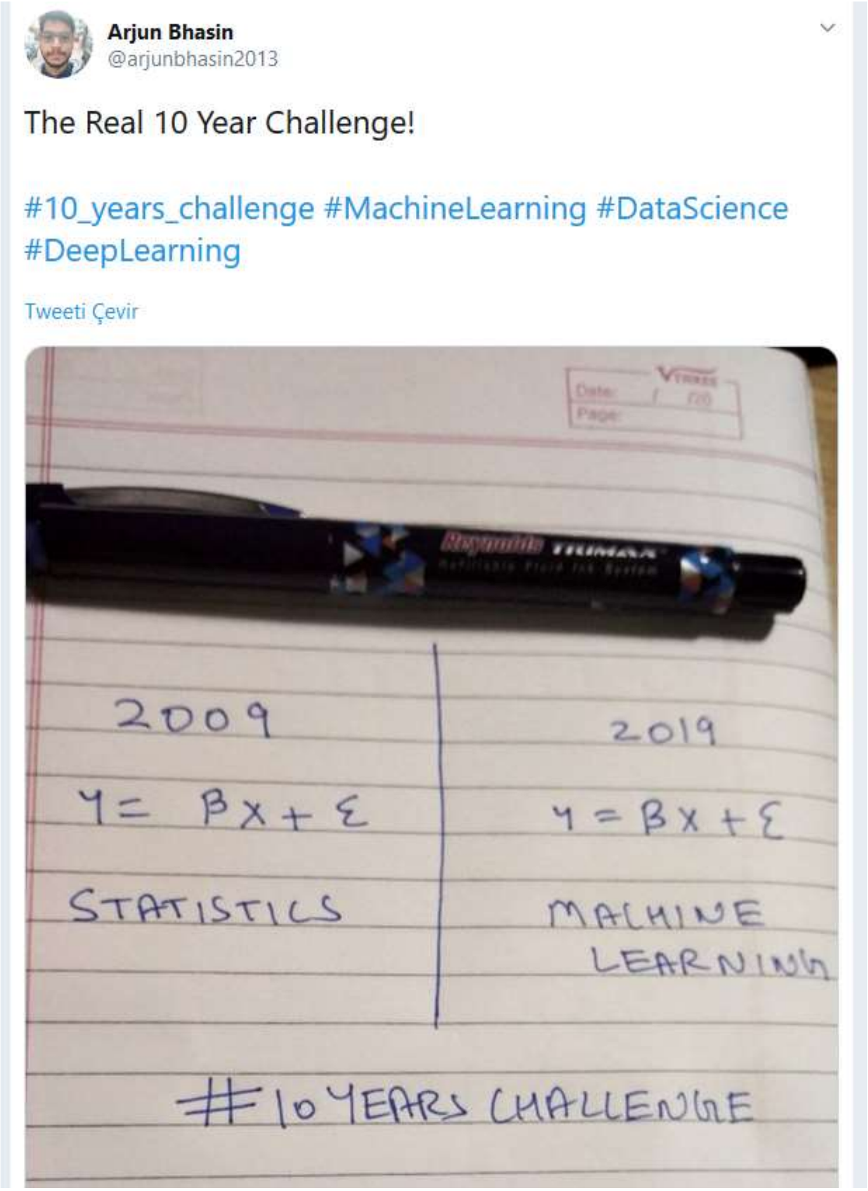
Deep learning algorithms can solve several computer vision tasks better than before



SEGMENTATION METHODS

Why is Deep Learning so popular today?

- Deep learning algorithms depend on mathematical developments from the 1980’s.
- Deep learning applications need huge amount of data and computational power.
- Nowadays, these requirements are reachable by companies.
- Complicated mathematics is not needed for Deep Learning.



SEGMENTATION METHODS

Deep Learning for Image Semantic Segmentation

- Deep Learning based image classification and object detection is one of the most popular research field nowadays.

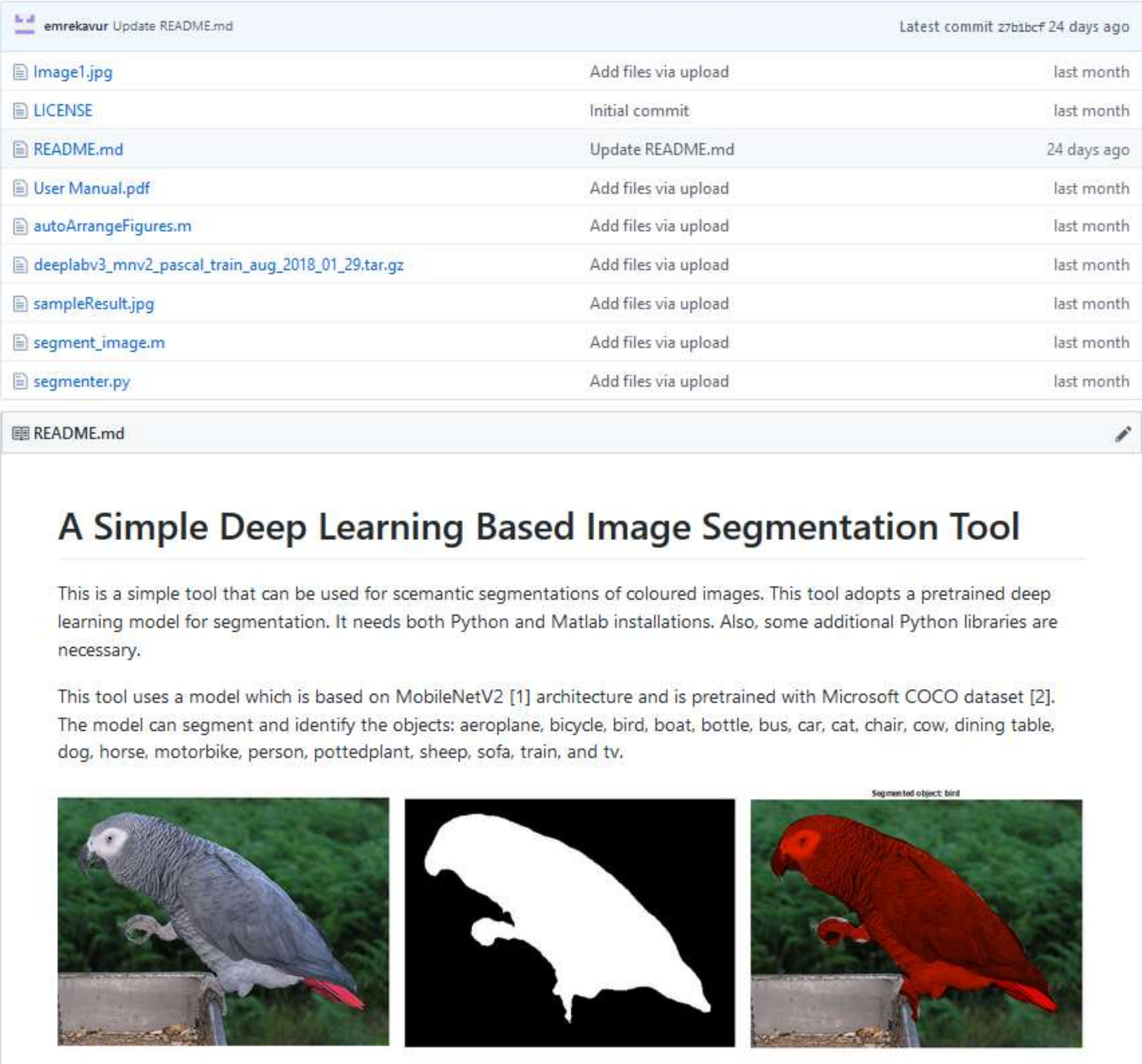
- Designing and building a Deep Learning based segmenter is a very challenging task.
- After the build, Deep Learning based solutions need a huge database and computational power for training.
- However, after the training process, segmentation is easy.

SEGMENTATION METHODS

Deep Learning for Image Semantic Segmentation

- Once a Deep Learning based segmenter is trained, it can be used for semantic segmentation of different inputs.

- That is why, creating a reliable segmenters is easier than ever before.



emrekavur Update README.md — Latest commit 27b1bcf 24 days ago

Image1.jpg	Add files via upload	last month
LICENSE	Initial commit	last month
README.md	Update README.md	24 days ago
User Manual.pdf	Add files via upload	last month
autoArrangeFigures.m	Add files via upload	last month
deeplabv3_mnv2_pascal_train_aug_2018_01_29.tar.gz	Add files via upload	last month
sampleResult.jpg	Add files via upload	last month
segment_image.m	Add files via upload	last month
segmenter.py	Add files via upload	last month

README.md

A Simple Deep Learning Based Image Segmentation Tool

This is a simple tool that can be used for scemantic segmentations of coloured images. This tool adopts a pretrained deep learning model for segmentation. It needs both Python and Matlab installations. Also, some additional Python libraries are necessary.

This tool uses a model which is based on MobileNetV2 [1] architecture and is pretrained with Microsoft COCO dataset [2]. The model can segment and identify the objects: aeroplane, bicycle, bird, boat, bottle, bus, car, cat, chair, cow, dining table, dog, horse, motorbike, person, pottedplant, sheep, sofa, train, and tv.

Segmented object: bird

https://github.com/emrekavur/semantic-segmenter-tool

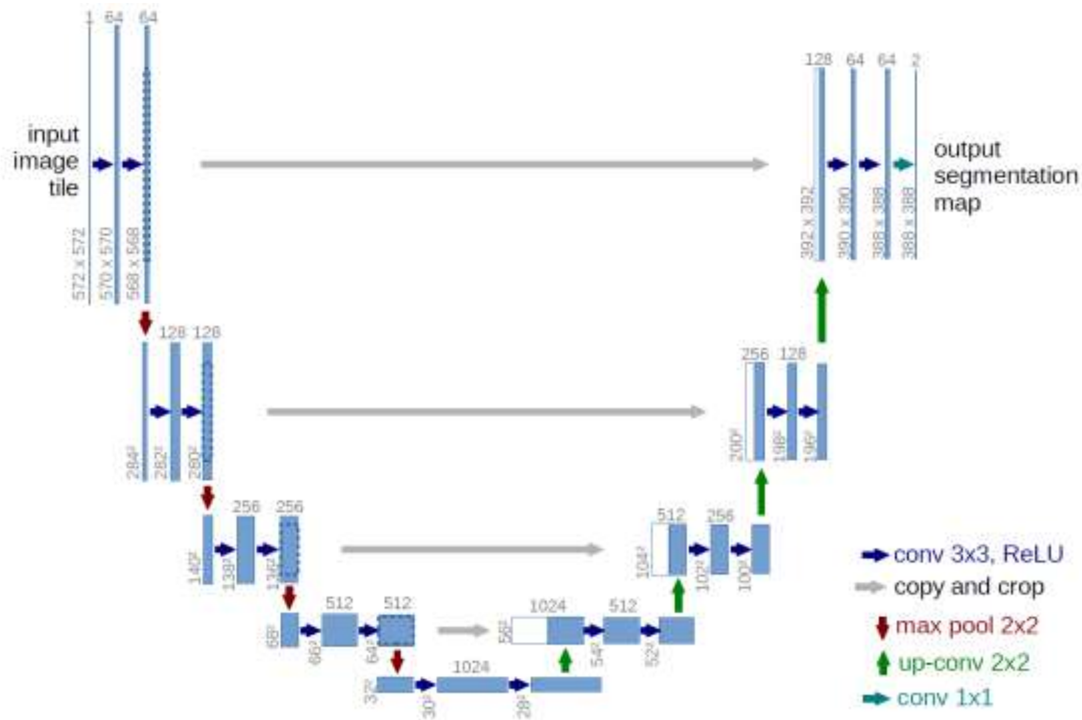
Deep Learning for Medical Image Segmentation

Deep Learning for organ segmentation has become tremendously popular in the last five years. The most popular DL-based segmentation solutions are:

1. U-net: Ronneberger, Olaf; Fischer, Philipp; Brox, Thomas (2015). "U-Net: Convolutional Networks for Biomedical Image Segmentation".
2. DeepMedic: Konstantinos Kamnitsas, Christian Ledig, Virginia F.J. Newcombe, Joanna P. Simpson, Andrew D. Kane, David K. Menon, Daniel Rueckert, and Ben Glocker, “Efficient Multi-Scale 3D CNN with Fully Connected CRF for Accurate Brain Lesion Segmentation”, Medical Image Analysis, 2016.
3. Dense V-Networks: E. Gibson et al., "Automatic Multi-Organ Segmentation on Abdominal CT With Dense V-Networks," in IEEE Transactions on Medical Imaging, vol. 37, no. 8, pp. 1822-1834, Aug. 2018.
4. V-Net: F. Milletari, N. Navab and S. Ahmadi, "V-Net: Fully Convolutional Neural Networks for Volumetric Medical Image Segmentation," 2016 Fourth International Conference on 3D Vision (3DV), Stanford, CA, 2016, pp. 565-571.

Deep Learning for Medical Image Segmentation

- The vast majority of papers in the recent literature are based on the a similar architecture.
- For example, all submission to our CHAOS segmentation challenge are based on Deep Learning based. Almost all of them use an U-net architecture

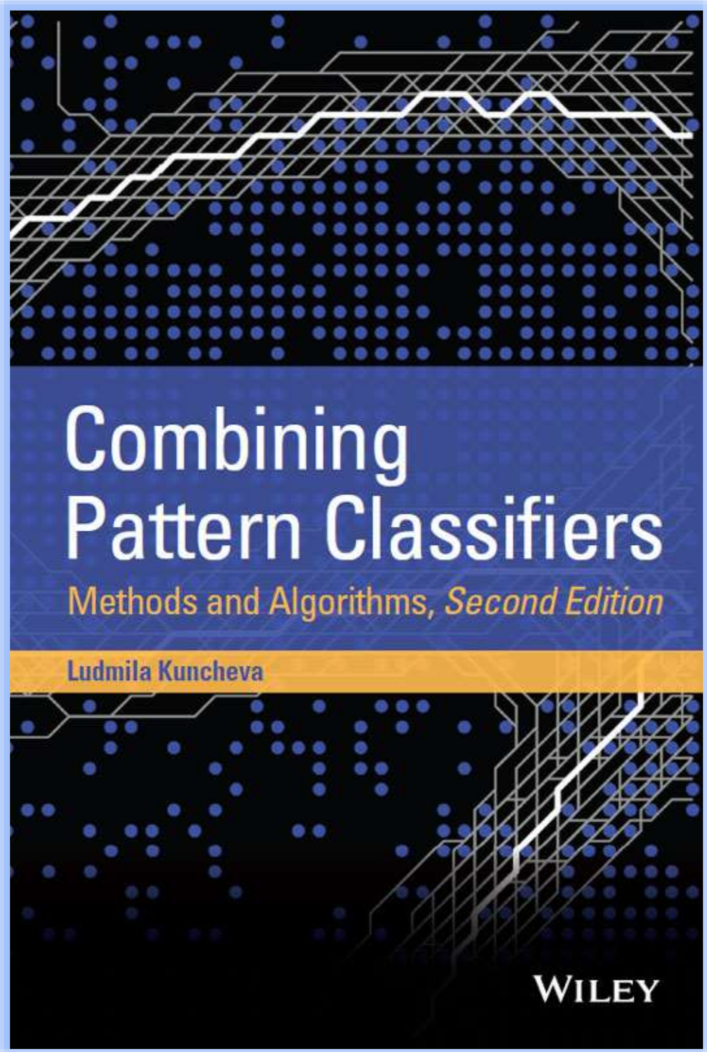


https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

SEGMENTATION METHODS

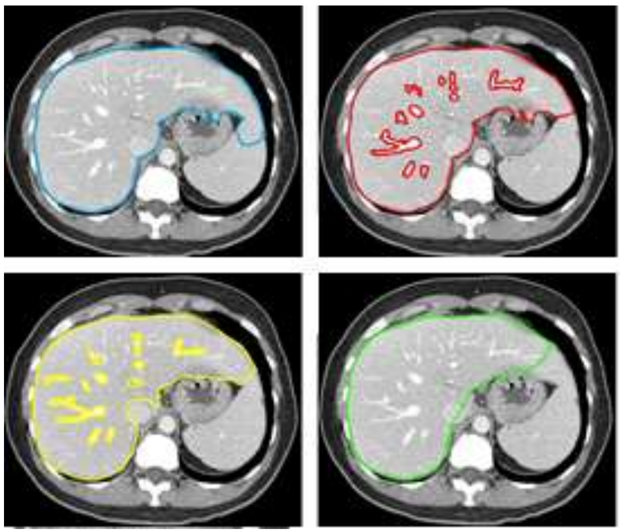
Classifier Ensemble

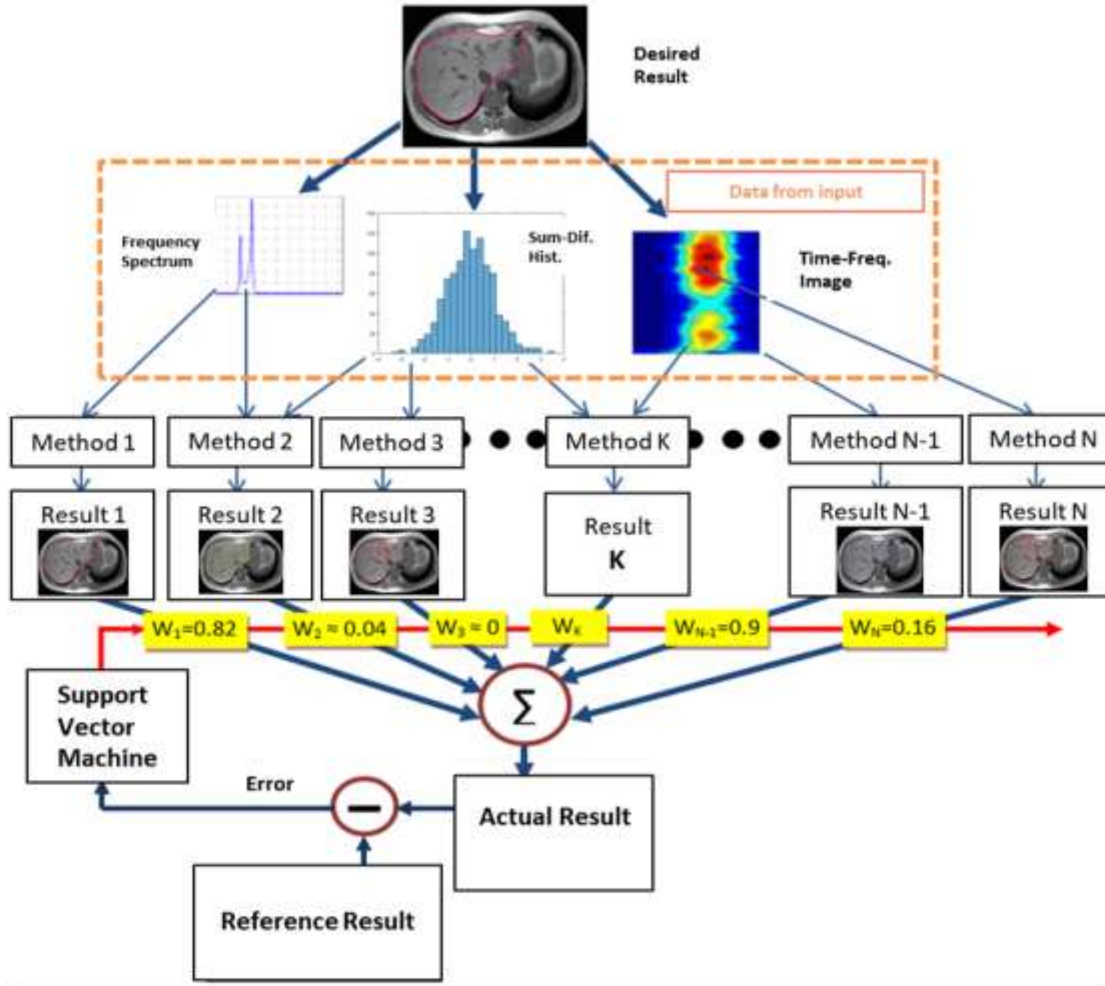
- Ensemble of classifiers is an alternative approach for segmentation applications.
- Combination of multiple, diverse and complementary methods may outperform many single segmentation algorithms.
- There is no comprehensive works about classifier ensemble in the medical image segmentation field.



SEGMENTATION METHODS

Classifier Ensemble





PERFORMANCE OF SEGMENTATION METHODS

Grand Challenges

Grand Challenges in Biomedical Image Analysis

Every year, thousands of papers are published that describe new algorithms to be applied to medical and biomedical images, and various new products appear on the market based on such algorithms. But few papers and products provide a fair and direct comparison of the newly proposed solution with the state-of-the-art. We believe that such comparisons can help the research community and industry to develop better algorithms. We support the organization of these comparative studies and the dissemination of their results.

Organizing and participating in challenges is not the only way to facilitate better comparisons between new and existing solutions. If it were easy to publish and share your data, and the code you used to evaluate your algorithm's performance on that data, and possibly the algorithm itself, others could directly compare their approach to yours, using the same test data and the same evaluation metrics. With this site we provide tools to make it as easy as possible for you to publish your data and your evaluation for any paper you've written.

Why Challenges? describes the rationale for organizing grand challenges, provides advice for those who want to organize such events, and discusses where we hope the field will move to next.

All Challenges provides an overview of all previous, ongoing and upcoming challenges in biomedical image analysis that we are aware of. Drop us a note if you want your event listed on this overview.

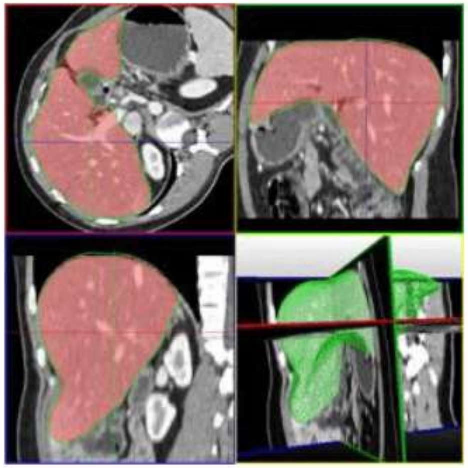
https://grand-challenge.org

PERFORMANCE OF SEGMENTATION METHODS

Sliver07

- Sliver 07 is the first grand challenge about liver segmentation.
- It was organized within the 10th International Conference on Medical Image Computing and Computer Assisted Intervention (MICCAI) at 29. October 2007, Brisbane, Australia.
- There are 20 train (image sets + ground truths) and 20 test (only image sets) of abdomen CT.

Segmentation of the Liver 2007

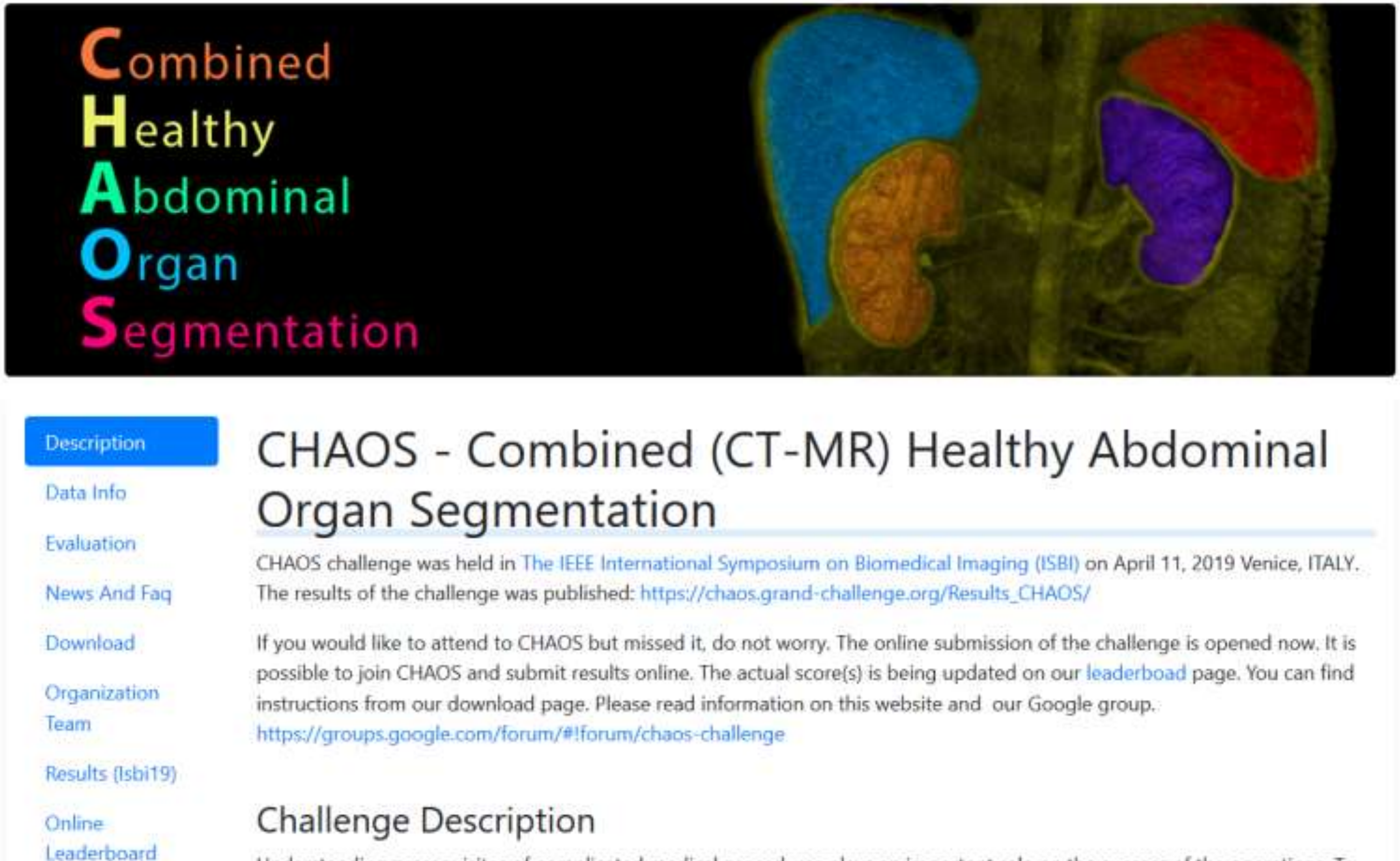


http://www.sliver07.org
https://sliver07.grand-challenge.org

3D Segmentation in the Clinic: A Grand Challenge, *Bram van Ginneken, Tobias Heimann, Martin Styner*
http://mbi.dkfz-heidelberg.de/grand-challenge2007/web/p7.pdf

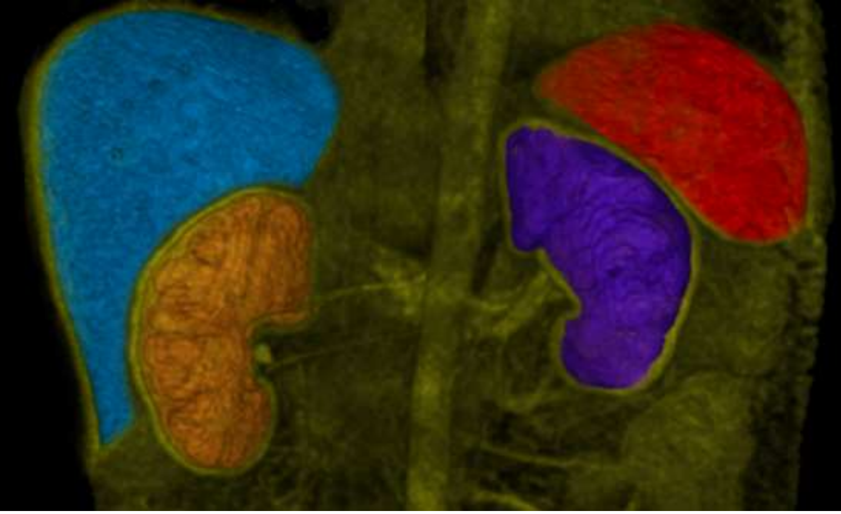
PERFORMANCE OF SEGMENTATION METHODS

CHAOS - Combined (CT-MR) Healthy Abdominal Organ Segmentation

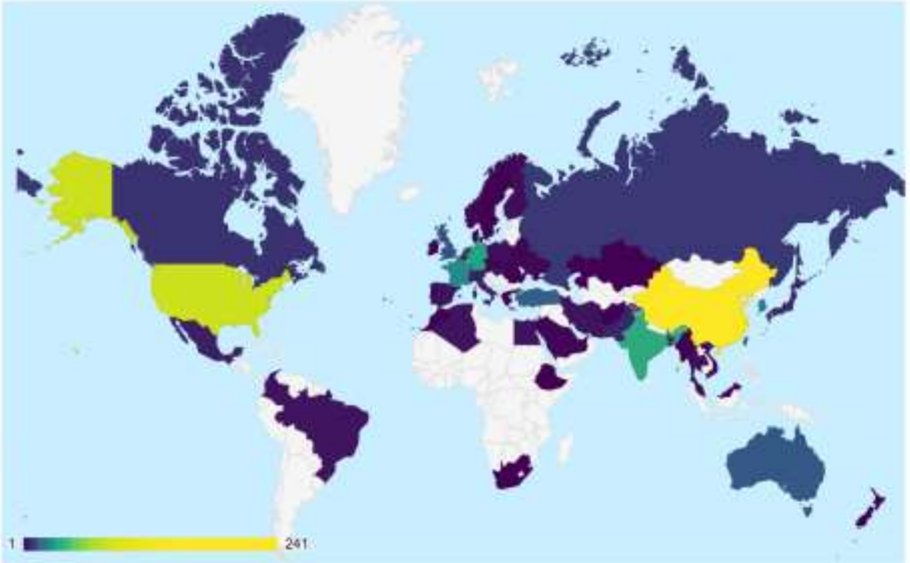


https://chaos.grand-challenge.org/

Combined Healthy Abdominal Organ Segmentation



- In the literature, CHAOS is the <u>first</u> challenge that;
  - ➢ includes abdomen MRI scans.
  - ➢ includes cross modality tasks.
- Currently CHAOS has 780 participants from 38 different countries.
- CHAOS is the most popular challenge hosted on grand-challenge.org website in 2019.
- Registrations with only official e-mail accounts are accepted.



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

Combined
Healthy
Abdominal
Organ
Segmentatio

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- CHAOS is organized by a relatively small team from different disciplines.

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Abdominal
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Segmentation

- CHAOS has started in The IEEE International Symposium on Biomedical Imaging (ISBI) on April 11, 2019 Venice, ITALY

- In two months, there are still more than 50 result submission.

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Current results of CHAOS

In this page, results of the online submissions are presented for each task. The leaderboard is being updated after each online submission.

Task 1: Liver Segmentation (CT-MRI)

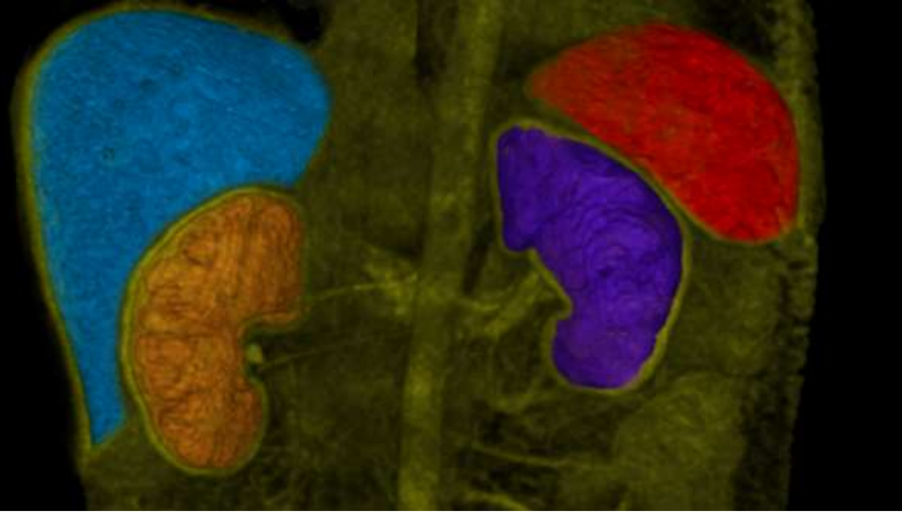
Team Name	Date	SCORE	Dice	Dice_Scr	RAVD	RAVD_scr	ASSD	ASSD_scr	M
FightHCC2D	07/06/19	72.765	0.904	87.569	3.542	50.566	4.996	83.466	31
FightHCC3D	07/06/19	70.557	0.899	86.882	3.279	47.339	4.801	82.737	31
12Sigma	10/06/19	68.026	0.931	91.805	5.34	37.302	2.479	83.473	30
PKDIAv2	07/05/19	50.661	0.854	84.146	6.654	21.657	9.767	75.839	46
MILab2	14/06/19	49.289	0.899	86.832	11.725	12.252	3.927	73.821	80
METU_MMLAB_v102	22/04/19	42.542	0.863	75.942	18.008	14.117	8.506	60.364	62

Task 2: Liver Segmentation (CT only)

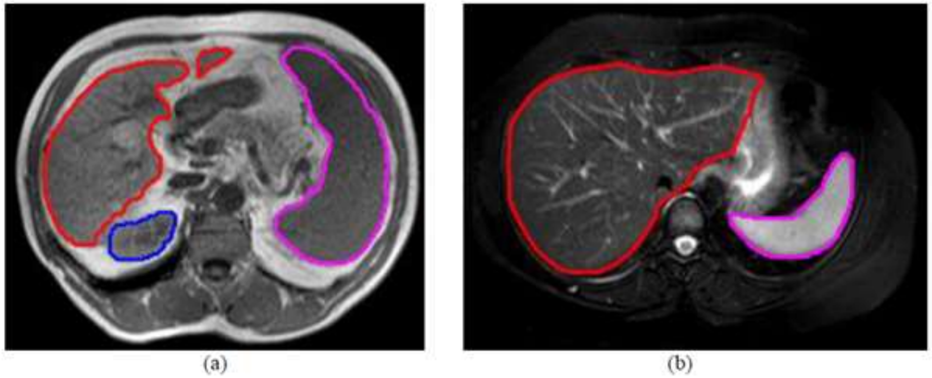
Team Name	Date	SCORE	Dice	Dice_Scr	RAVD	RAVD_scr	ASSD	ASSD_scr	M
FightHCC3D	07/06/19	84.644	0.979	97.947	1.547	69.053	0.692	95.387	14
PKDIAv2	07/05/19	82.457	0.978	97.789	1.32	73.597	0.891	94.059	21
FightHCC2D	07/06/19	82.167	0.977	97.667	1.488	70.235	0.957	93.623	19
DLIPLab	14/06/19	80.963	0.963	96.315	1.611	67.772	1.231	91.796	19
AbdomenNet	23/05/19	80.752	0.964	96.387	1.726	65.578	1.214	91.908	1
Dawn v2	26/05/19	77.177	0.965	96.489	2.239	58.537	1.422	90.521	22
Dawn	05/05/19	75.998	0.965	96.526	2.268	54.645	1.387	90.753	23
12Sigma	10/06/19	74.429	0.957	95.719	2.326	61.034	1.718	88.55	28
OncoRadiomics	24/05/19	74.347	0.972	97.234	1.618	67.643	2.143	85.711	42
Dense V-Networks(Post)	23/05/19	73.784	0.953	95.263	2.887	50.15	1.568	89.547	23
DeepMedic(Post)	23/05/19	73.317	0.967	96.685	3.179	51.348	1.24	91.732	27
NEHUSGGSv2	14/05/19	65.18	0.939	93.9	4.597	32.49	2.382	84.117	30
V-Net(Post)	23/05/19	60.01	0.896	86.853	6.783	31.581	4.873	76.542	42
Dense V-Networks	23/05/19	59.365	0.951	95.15	2.92	50.131	2.451	83.657	119
OncoRadiomicsV2	14/06/19	58.374	0.936	93.627	11.59	0	2.256	84.962	27
BITLab	24/05/19	56.82	0.953	91.933	4.561	53.327	11.394	78.268	158
DeepMedic	23/05/19	54.428	0.954	95.368	2.341	56.076	7.92	61.87	142
UniSegm	28/05/19	53.76	0.919	91.851	7.825	18.057	3.728	75.148	44
NEHUSGGS	09/05/19	52.701	0.935	93.517	4.48	37.187	4.345	71.767	111
V-Net	23/05/19	52.604	0.894	86.786	6.794	31.872	5.535	74.869	80
KCliver	17/05/19	49.548	0.756	75.55	24.22	15.291	148.847	66.084	178
MILab2	14/06/19	48.834	0.935	93.521	6.737	15.366	4.847	67.995	85
MILab	14/06/19	46.352	0.935	93.469	6.843	13.451	5.135	66.294	92
AIExplore2	11/06/19	25.354	0.483	34.204	2.762	46.304	28.832	18.282	105
AIExplore5	14/06/19	25.354	0.483	34.204	2.762	46.304	28.832	18.282	105
Liver_AI_Team2	28/04/19	25.304	0.479	33.909	2.809	50.205	30.513	15.447	12
AIExplore	10/06/19	23.016	0.478	34.044	4.175	35.539	28.547	18.708	102
Liver_AI_Team	22/04/19	14.518	0.496	37.849	14.423	0	27.123	18.28	121

https://chaos.grand-challenge.org/CHAOS_Online_Leaderboard/

Combined
Healthy
Abdominal
Organ
Segmentation



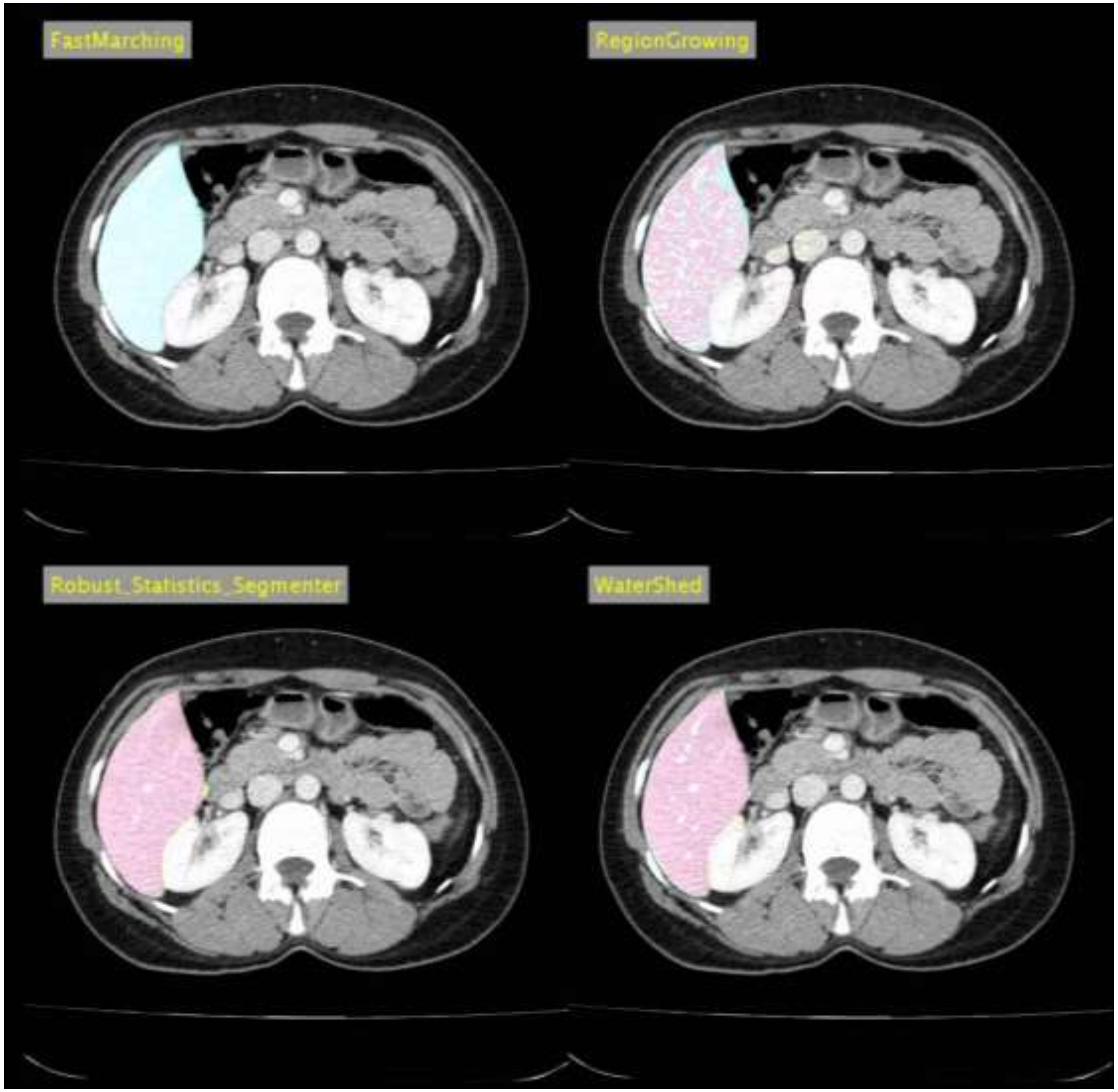
- There are more than 10000 DICOM files in CHAOS.
- Each of these files was labelled manually by team members to construct ground truth images.
- All labelled images were annotated by three different radiologists.
- Four different metrics are used for evaluation.
- Total evaluation code for all tasks has more than 1300 lines of code written in MATLAB.



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

PERFORMANCE OF SEGMENTATION METHODS

- Segmented images guide physician’s actions.
- Hence, the success of the segmentation process is very critical.
- There are some metrics to compare two objects in terms of volume, shape, etc.
- To measure performance, ground truth (reference) images are necessary.



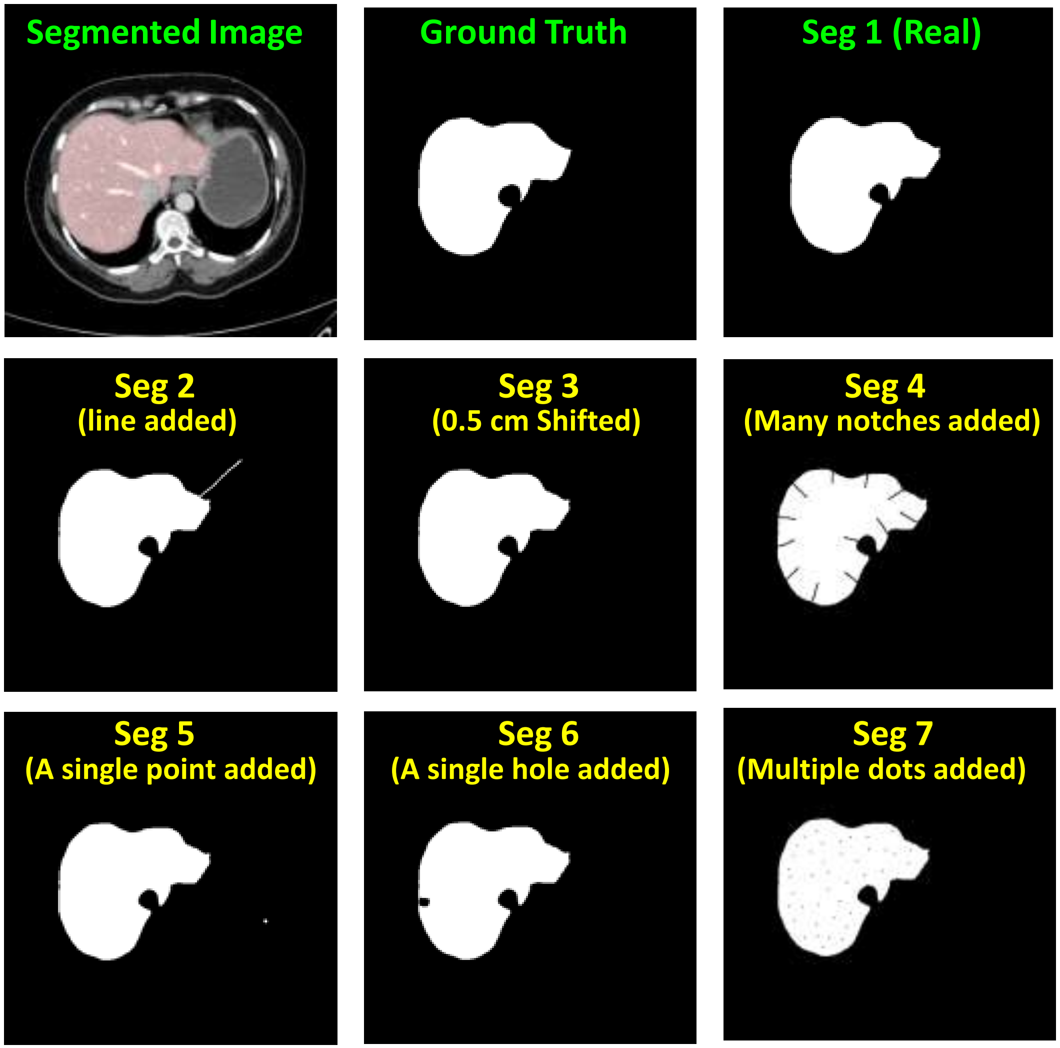
PERFORMANCE OF SEGMENTATION METHODS

Metrics

- It is a very common mistake to use only one metric to evaluate segmentation performance. (DICE is the most popular single metric.)
- Combination of multiple metrics guarantees a reliable comparison of segmentations.
- Therefore, in CHAOS there are four metrics:
    1. Sørensen–Dice coefficient (DICE): Provides information about the overlapping parts of segmented and reference volumes in mm3. (Takes value 1 for a perfect segmentation)
    2. Relative absolute volume difference (RAVD): Also provides information about the differences between volumes of segmented and reference organs, but values the differences more than overlap (0% for a perfect segmentation).
    3. Average symmetric surface distance (ASSD): Determines the average difference between the surface of the segmented object and the reference in 3D. (0 mm for a perfect segmentation).
    4. Maximum symmetric surface distance (MSSD) or Hausdorff distance: Determines the maximum difference between the surface of the segmented object and the reference in 3D. MSSD is very important for surgical operations as it determines the maximum margin of error (0 mm for a perfect segmentation).

PERFORMANCE OF SEGMENTATION METHODS

Metrics comparison



	DICE	RAVD	ASSD (mm)	MSSD (mm)
Seg 1	0.987	0.805	0.696	3.681
Seg 2	0.984	0.159	2.99	53.731
Seg 3	0.858	0.805	7.406	13.825
Seg 4	0.975	3.089	3.342	22.013
Seg 5	0.986	0.722	1.398	81.531
Seg 6	0.984	1.406	0.864	11.621
Seg 7	0.984	1.327	4.06	44.328

	DICE Score	RAVD Score	ASSD Score	MSSD Score	Final Score
Seg 1	98.67	83.902	95.357	93.865	92.948
Seg 2	98.351	96.819	80.064	10.449	71.42
Seg 3	85.764	83.902	50.624	76.959	74.312
Seg 4	97.501	38.216	77.72	63.311	69.187
Seg 5	98.629	85.556	90.678	0	68.716
Seg 6	98.363	71.876	94.243	80.632	86.278
Seg 7	98.403	73.467	72.931	26.119	67.73

CONCLUSION

- While population is increasing and technology is developing, medical imaging systems will always be a popular research field.
- Organ segmentation is one of the most requested medical image processing tools by the medical community.
- Deep Learning segmentation is the most preferred solution in the last five years.
- Despite of their success, Deep Learning solutions have problems such as high demands for computational power and large volumes of labelled data.
- Classifier ensembles have the potential of being a better alternative and a more convenient solution for the organ segmentation problem.

QUESTIONS

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