Medical image processing: format, display, and applications

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2023/08/23

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The software and files needed in the workshop

1. Irfanview
2. 3 medical image files from https://shorturl.at/ekntu
3. MicroDicom from https://shorturl.at/ekntu
4. Dicompyler
5. 3D slicer and its extension 'SlicerRT'
6. Kira anonymizer

Outline

1. Format of medical images
2. Issues about data anonymization

3. Polyp segmentation in colonoscopy
4. Organ segmentation in CT
5. Tumor segmentation in brain MRI

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Scenario

You: “Doc, I need some medical image data to do imaging processing research.”

Doc: “OK. Let me download some cases from PACS.” (5 minutes later…)

Doc: “Here are some patient data, which format do you want?”

Option 1: “*.jpg”

Option 2: “*.dcm”

Your choice is ?

1. Irfanview
2. 3 medical image files from https://shorturl.at/ekntu
3. MicroDicom from ekntu
4. Dicompyler
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Picture Archiving Communication System (PACS)

- The main purpose of PACS is to digitally store all the images in the medical system and transmit them to the same system via the network for users to read and interpret the images on the remote computer terminal. At the same time, it can also be used as a tool for image transmission and exchange in different medical systems. It can also further assist doctors in diagnosis, teaching and medical research.

- A complete PACS should include functions such as image capture, storage, output, transmission, display, and HIS/RIS integration and exchange of data. A successful PACS not only requires powerful hardware, but also relies on perfect software functions and operating procedures to achieve a film-free hospital.

Information system used in a hospital

A hospital information system has many different aspects incorporated within itself.

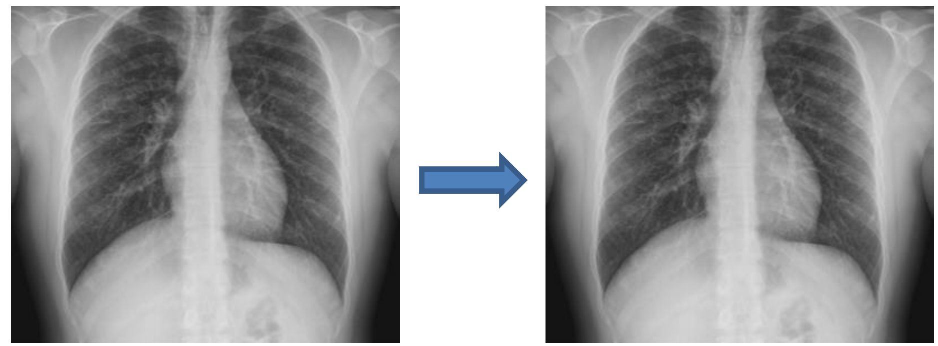
Technology allows for the information within these systems to flow more easily and more accurately.

Some of these systems include:

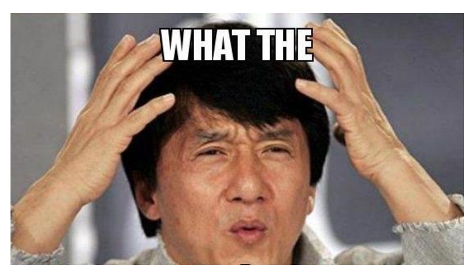
1- Laboratory Information System (LIS)
2- Nursing Information System (NIS)
3- Picture Archiving Communication System (PACS)
4- Radiology Information System (RIS)
5- Pharmacy Information System (PIS)
6- Administration Information System
7- Financial Information System (FIS)

Back to question: jpg or dcm?

- JPG is good for its high compression ratio
  - 5MB → 500 kb
  - Images looks the same



- JPG is not good due to the lossy compression
  - Groundtruth: [0,0,0,1,1,1] → [0, 0.1, 0.98, 0.98, 1.01, 1]
  - AI segmentation model:



Have some image processing concepts before doing AI.

DICOM History

Slides from Prof. Rujchai Ung-arunyawee at KKU, Thailand

- Based on ACR-NEMA standard
  - ACR (American college of radiology)
  - NEMA (National Electrical Manufacturers Association)
  - 1982 - ACR and NEMA form a joint committee
  - 1985 - Publication of Version 1.0
  - 1988 - Compression and Mag Tape Standards
  - 1988 - Publication of Version 2.0
  - 1989 - Began work on Network Version with HIS/RIS

The name was changed to separate the standard from the originating body

- 1991 - Release of Parts 1 and 8 of DICOM
- 1992 - RSNA demonstration, Part 8
- 1993 - DICOM Parts 1-9 approved. RSNA demonstration of ALL parts
- 1994 - Part 10: Media Storage and File Format
- 1995 - Parts 11,12, and 13 plus Supplements

DICOM is the ONLY standard in the world that covers the exchange of medical images

The DICOM File Format

- Header containing
  - the patient's name / id
  - type of media (CT, MRI, audio recording, etc.)
  - image dimensions
  - …
- Body, containing «information objects»
  - medical reports
  - audio recordings
  - images

To read DICOM header in python: install ‘pydicom’

https://github.com/pydicom/pydicom

Example in Chinese: https://officeguide.cc/python-pydicom-read-edit-dicom-tutorial-examples/

DICOM Value Representations (VR)

- All DICOM attributes are formatted according to 27 value representation (VR) types

Patient in
Real World

Patient object in
DICOM World

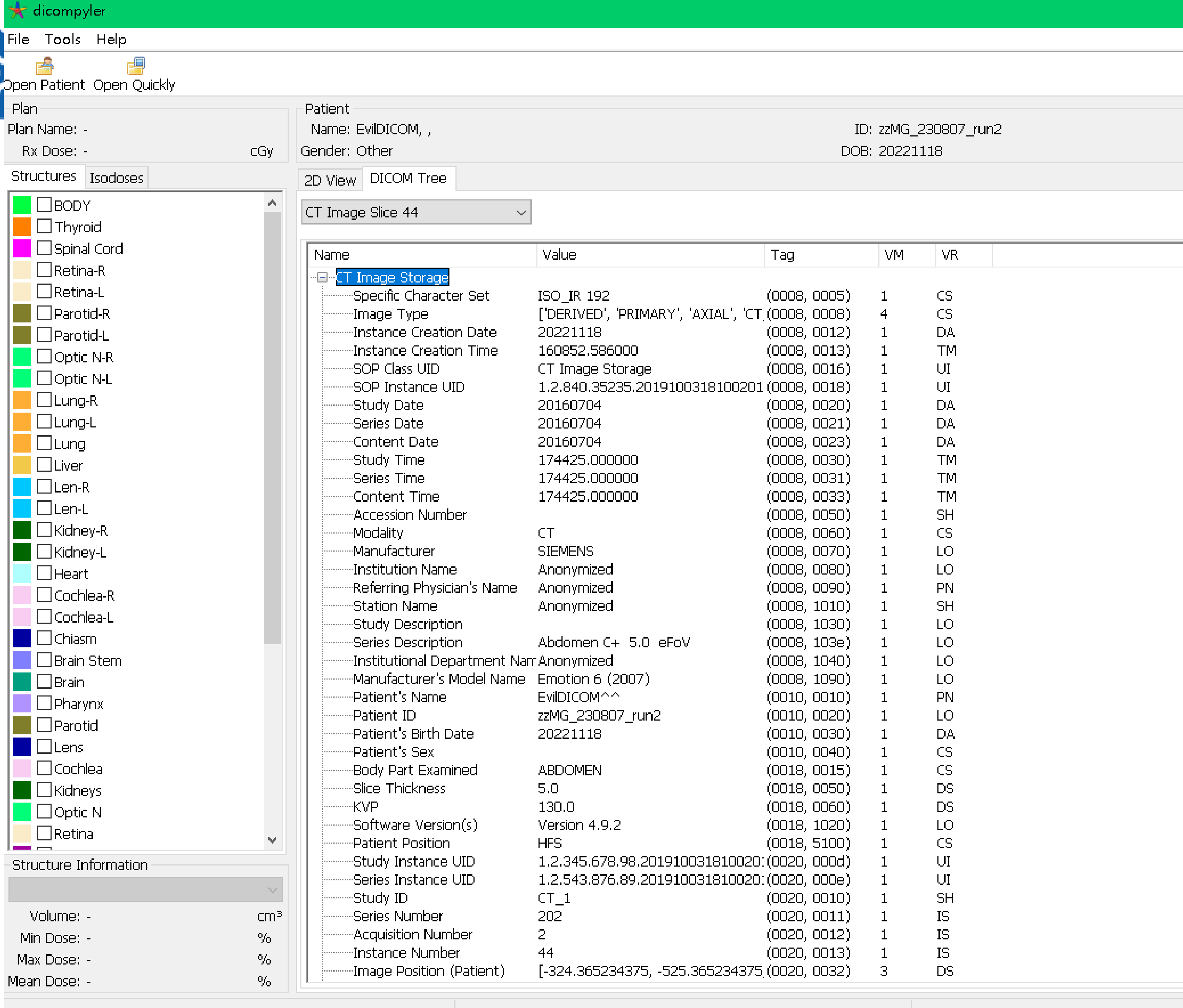
Name	John Smith
ID	123456
DOB	19681108
Weight	75.5
Sex	M
…….	

Patient IOD
(Information
Object
Definition)

DICOM Value Representations (VR)

Value Representation	Description
AE	Application Entity
AS	Age String
AT	Attribute Tag
CS	Code String
DA	Date
DS	Decimal String
DT	Date/Time
FL	Floating Point Single (4 bytes)
FD	Floating Point Double (8 bytes)
IS	Integer String
LO	Long String
LT	Long Text
OB	Other Byte

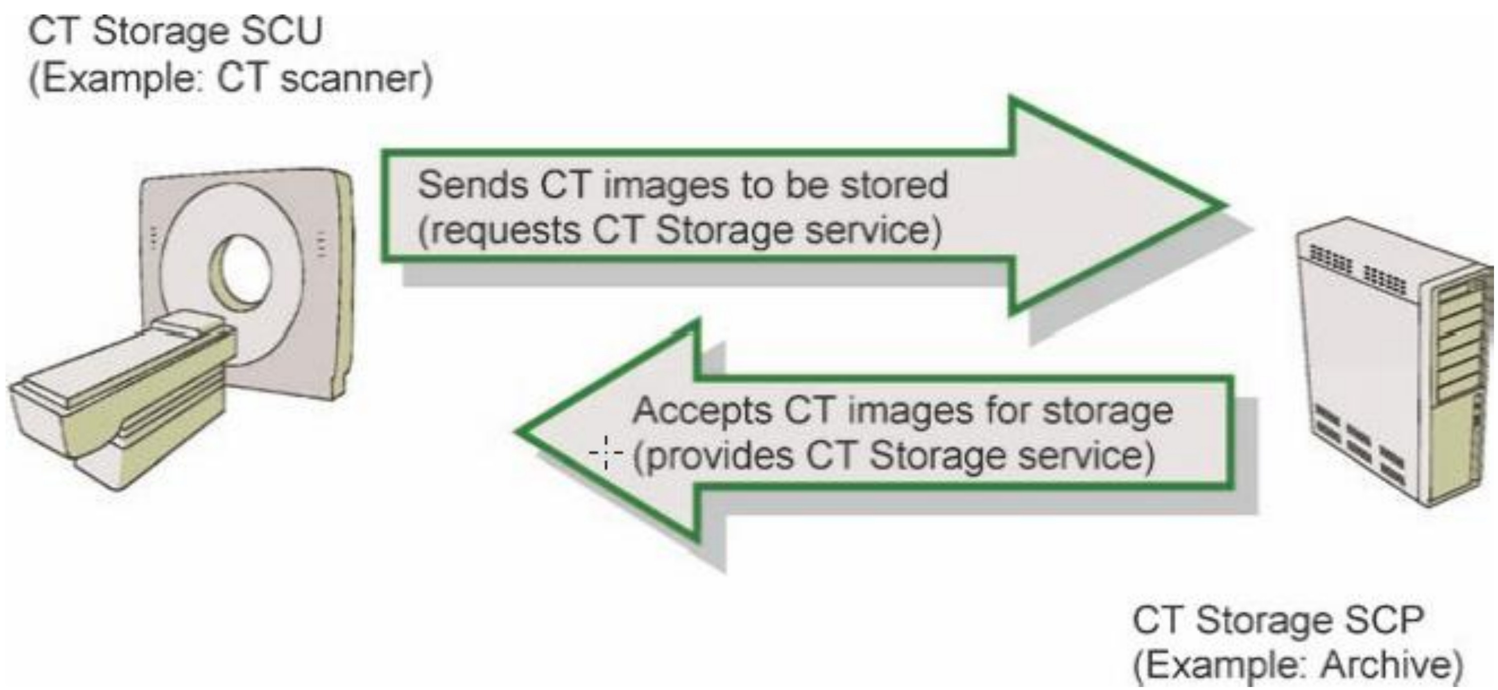
Value Representation	Description
OF	Other Float
OW	Other Word
PN	Person Name
SH	Short String
SL	Signed Long
SQ	Sequence of Items
SS	Signed Short
ST	Short Text
TM	Time
UI	Unique Identifier
UL	Unsigned Long
UN	Unknown
US	Unsigned Short
UT	Unlimited Text


dicompyler
File Tools Help
Open Patient Open Quickly
Plan
Plan Name: -
Rx Dose: - cGy
Patient
Name: EvilDICOM, ,
Gender: Other
ID: zzMG_230807_run2
DOB: 20221118
Structures
Isodoses
BODY
Thyroid
Spinal Cord
Retina-R
Retina-L
Parotid-R
Parotid-L
Optic N-R
Optic N-L
Lung-R
Lung-L
Lung
Liver
Len-R
Len-L
Kidney-R
Kidney-L
Heart
Cochlea-R
Cochlea-L
Chiasm
Brain Stem
Brain
Pharynx
Parotid
Lens
Cochlea
Kidneys
Optic N
Retina
Structure Information
Volume: - cm³
Min Dose: - %
Max Dose: - %
Mean Dose: - %
2D View
DICOM Tree
CT Image Slice 44
Name Value Tag VM VR
CT Image Storage
Specific Character Set ISO_IR 192 (0008, 0005) 1 CS
Image Type ['DERIVED', 'PRIMARY', 'AXIAL', 'CT (0008, 0008) 4 CS
Instance Creation Date 20221118 (0008, 0012) 1 DA
Instance Creation Time 160852.586000 (0008, 0013) 1 TM
SOP Class UID CT Image Storage (0008, 0016) 1 UI
SOP Instance UID 1.2.840.35235.2019100318100201 (0008, 0018) 1 UI
Study Date 20160704 (0008, 0020) 1 DA
Series Date 20160704 (0008, 0021) 1 DA
Content Date 20160704 (0008, 0023) 1 DA
Study Time 174425.000000 (0008, 0030) 1 TM
Series Time 174425.000000 (0008, 0031) 1 TM
Content Time 174425.000000 (0008, 0033) 1 TM
Accession Number (0008, 0050) 1 SH
Modality CT (0008, 0060) 1 CS
Manufacturer SIEMENS (0008, 0070) 1 LO
Institution Name Anonymized (0008, 0080) 1 LO
Referring Physician's Name Anonymized (0008, 0090) 1 PN
Station Name Anonymized (0008, 1010) 1 SH
Study Description (0008, 1030) 1 LO
Series Description Abdomen C+ 5.0 eFoV (0008, 103e) 1 LO
Institutional Department Nam Anonymized (0008, 1040) 1 LO
Manufacturer's Model Name Emotion 6 (2007) (0008, 1090) 1 LO
Patient's Name EvilDICOM^^ (0010, 0010) 1 PN
Patient ID zzMG_230807_run2 (0010, 0020) 1 LO
Patient's Birth Date 20221118 (0010, 0030) 1 DA
Patient's Sex (0010, 0040) 1 CS
Body Part Examined ABDOMEN (0018, 0015) 1 CS
Slice Thickness 5.0 (0018, 0050) 1 DS
KVP 130.0 (0018, 0060) 1 DS
Software Version(s) Version 4.9.2 (0018, 1020) 1 LO
Patient Position HFS (0018, 5100) 1 CS
Study Instance UID 1.2.345.678.98.20191003181002 (0020, 000d) 1 UI
Series Instance UID 1.2.543.876.89.20191003181002 (0020, 000e) 1 UI
Study ID CT_1 (0020, 0010) 1 SH
Series Number 202 (0020, 0011) 1 IS
Acquisition Number 2 (0020, 0012) 1 IS
Instance Number 44 (0020, 0013) 1 IS
Image Position (Patient) [-324.365234375, -525.365234375 (0020, 0032) 3 DS

DICOM Services

- DICOM data attributes can be transmitted and processed between various DICOM devices and software (Applications)
- DICOM applications provide services to each other
- Particular services always associate with the data (IODs) that they process.
- These associations are called Service-Object Pairs (SOPs)

Example: CT Storage SOP



- CT image = DICOM IOD (DICOM data object).
- CT Storage = DICOM Service
- CT Scanner = SCU (Service Class User)
- Digital Archive = SCP (Service Class Provider)

Data Communication

- Information about each device is called Presentation Context.
- Data transfer begins with Handshaking on the presentation context.
- If the two applications can match their contexts, they can connect and start SCU-SCP processing.

DICOM Conformance Statement

- Each DICOM unit will be accompanied by its own DICOM Conformance Statement from the manufacturer
- This statement explains which SOPs (services) the unit supports, and to what extent (SCU, SCP, or both)
- For example, if you buy a digital archive that supports only CT Storage SCU (does not support CT Storage SCP) you won’t be able to store CT images in it. The archive won’t be able to provide the CT storage service.

Modalities compatible with DICOM

AS = Angioscopy血管鏡

BI = Biomagnetic Imaging生物磁場成像

CD = Color Flow Doppler彩色血流都卜勒

CF = Cinefluorography螢光電影照相術

CP = Colposcopy陰道鏡

CR = Computed Radiography電腦X光攝影

CS = Cystoscopy膀胱鏡檢查

CT = Computed Tomography X光斷層攝影術

DD = Duplex Doppler雙工都卜勒

DF = Digital Fluoroscopy數位螢光透視

DG = Diaphanography

DM = Digital Microscopy數位顯微鏡

DSA = Digital Subtraction Angiography數位減影心血管造影術

DX = Digital Radiography數位X光攝影

EC = Echocardiography超音波心動圖

ES = Endoscopy內視鏡

FA = Fluoresce in Angiography透視血管攝影

FS = Fundoscopy

HC = Hard Copy硬拷貝

LP = Laparoscopy腹腔鏡攝影

LS = Laser Surface Scan雷射體表掃描

Modalities compatible with DICOM

MA = Magnetic Resonance Angiography 磁共振血管攝影

MR = Magnetic Resonance磁共振

MS = Magnetic Resonance Spectroscopy 磁共振波譜

NM = Nuclear Medicine 核醫學

OT = Other其他

PT = Positron Emission Tomography (PET) 正電子發射斷層顯像

RF = Radio Fluoroscopy透視螢光攝影

RG = Radiographic Imaging (conventional film screen) X光成像

RTDOSE = Radiotherapy Dose放射治療劑量

RTIMAGE = Radiotherapy Image放射治療影像

RTPLAN = Radiotherapy Plan放射治療計劃

RTSTRUCT = Radiotherapy Structure Set

ST = Single-photon Emission Computed Tomography單光子放射斷層攝影

TG = Thermography熱影像技術

US = Ultrasound超音波檢查

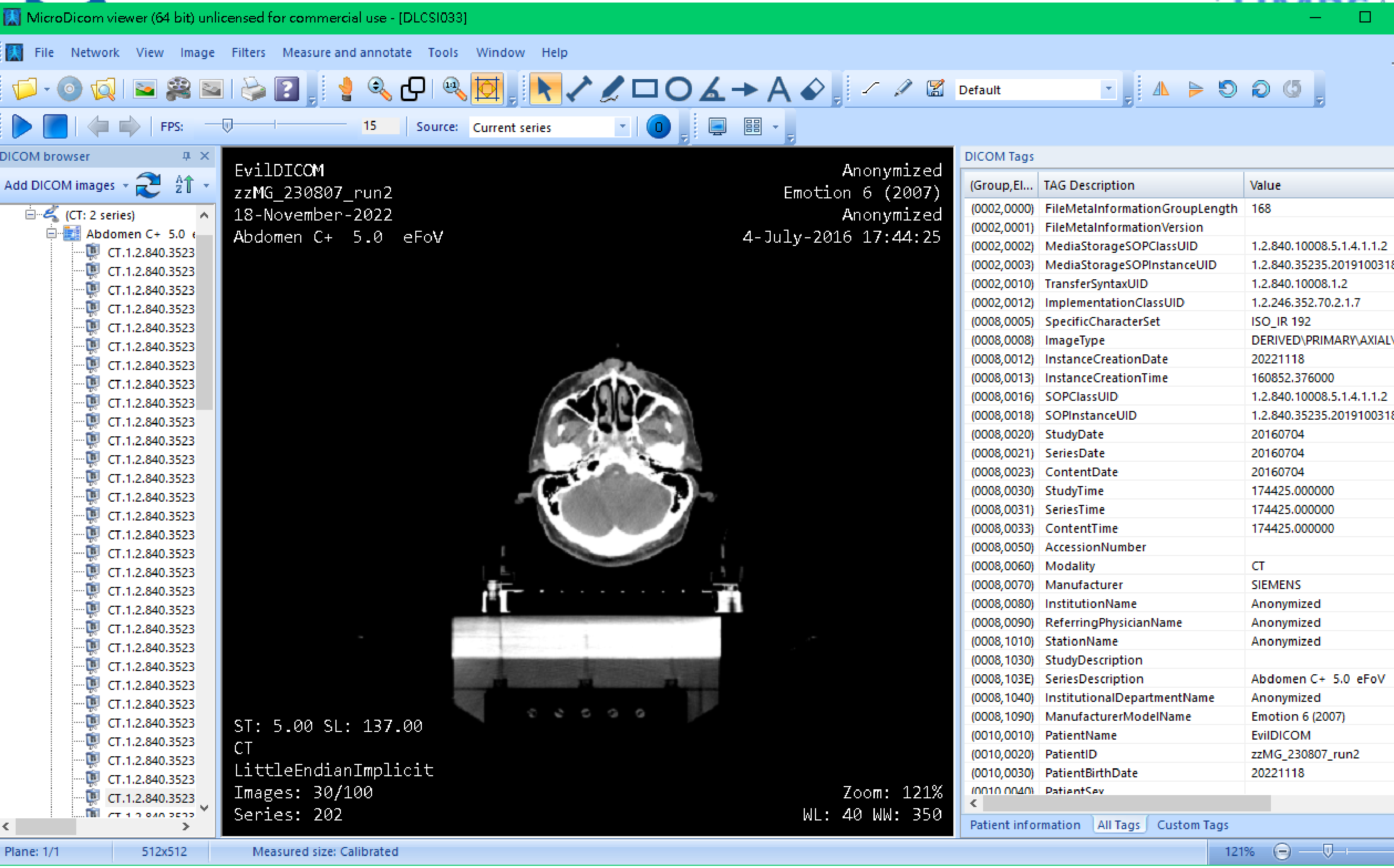
VF = Videofluorography

XA = X-Ray Angiography X光血管攝影

XC = eXternal Camera

ECG = Electrocardiograms心電圖

MicroDicom


MicroDicom viewer (64 bit) unlicensed for commercial use - [DLCSI033]
File Network View Image Filters Measure and annotate Tools Window Help
Default
FPS: 15 Source: Current series
DICOM browser
Add DICOM images
(CT: 2 series)
Abdomen C+ 5.0
CT.1.2.840.3523
EvilDICOM
zzMG_230807_run2
18-November-2022
Abdomen C+ 5.0 eFoV
Anonymized
Emotion 6 (2007)
Anonymized
4-July-2016 17:44:25
ST: 5.00 SL: 137.00
CT
LittleEndianImplicit
Images: 30/100
Series: 202
Zoom: 121%
WL: 40 WW: 350
DICOM Tags
(Group,El... TAG Description Value
(0002,0000) FileMetaInformationGroupLength 168
(0002,0001) FileMetaInformationVersion
(0002,0002) MediaStorageSOPClassUID 1.2.840.10008.5.1.4.1.1.2
(0002,0003) MediaStorageSOPInstanceUID 1.2.840.35235.201910031
(0002,0010) TransferSyntaxUID 1.2.840.10008.1.2
(0002,0012) ImplementationClassUID 1.2.246.352.70.2.1.7
(0008,0005) SpecificCharacterSet ISO_IR 192
(0008,0008) ImageType DERIVED\PRIMARY\AXIAL\
(0008,0012) InstanceCreationDate 20221118
(0008,0013) InstanceCreationTime 160852.376000
(0008,0016) SOPClassUID 1.2.840.10008.5.1.4.1.1.2
(0008,0018) SOPInstanceUID 1.2.840.35235.201910031
(0008,0020) StudyDate 20160704
(0008,0021) SeriesDate 20160704
(0008,0023) ContentDate 20160704
(0008,0030) StudyTime 174425.000000
(0008,0031) SeriesTime 174425.000000
(0008,0033) ContentTime 174425.000000
(0008,0050) AccessionNumber
(0008,0060) Modality CT
(0008,0070) Manufacturer SIEMENS
(0008,0080) InstitutionName Anonymized
(0008,0090) ReferringPhysicianName Anonymized
(0008,1010) StationName Anonymized
(0008,1030) StudyDescription
(0008,103E) SeriesDescription Abdomen C+ 5.0 eFoV
(0008,1040) InstitutionalDepartmentName Anonymized
(0008,1090) ManufacturerModelName Emotion 6 (2007)
(0010,0010) PatientName EvilDICOM
(0010,0020) PatientID zzMG_230807_run2
(0010,0030) PatientBirthDate 20221118
Patient information All Tags Custom Tags
Plane: 1/1 512x512 Measured size: Calibrated 121%

Why introducing the software

- Changing the contrast or brightness is not that convenient in python or Matlab.
- Comparing the two images below.

Fig. A

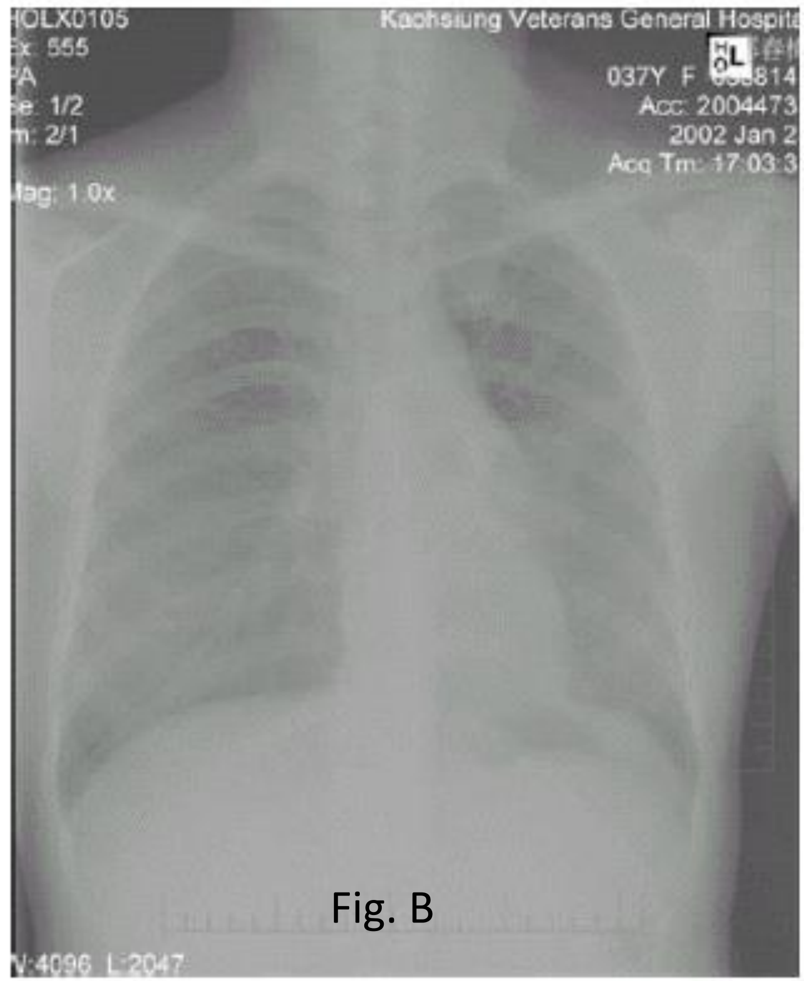


Fig. B

- Fig. A can be used for diagnosis, and Fig. B can’t due to its flatness.
- They are the same image, but are displayed by different software.
- Fig. B can’t recognize some DICOM information and therefore displayed the image linearly.

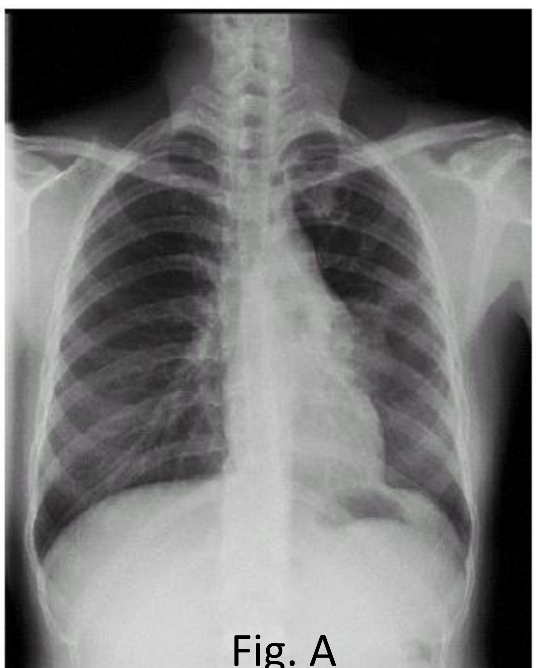
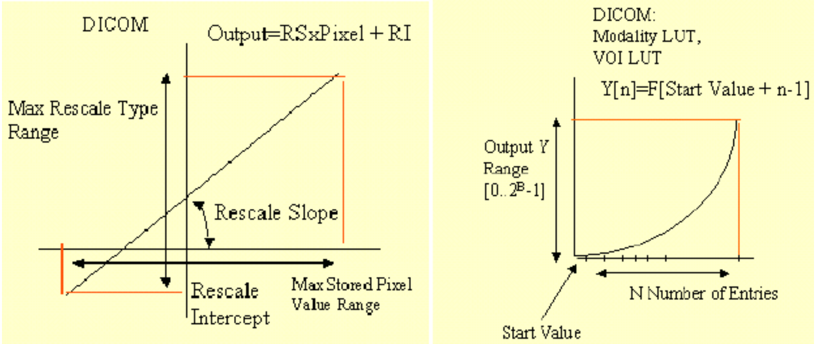


Fig. A

Fig. B

Display issue 1

- To display the chest X-ray image appropriately, we should transform its grayscale nonlinearly by checking ‘VOI LUT SEQ’ (Values of Interest, Look up Table, sequence).
- ‘VOI LUT SEQ’ is an important data element in DX (digital radiography) modality.
- If the value of tag (0008,0068) is ‘for presentation’, then ‘VOI LUT SEQ’ should exist.
- ‘VOI LUT SEQ’ contain 3 child data elements: LUT Descriptor, LUT Explanation, and LUT Data.
- The ‘LUT Data’ contains the information to convert pixel values into different grayscale illuminance on the screen.



Group - Element	Description	Type	Length	Value	Notes
0002 0000	Group Length	UL	4	192	
0002 0001	File Meta Information Version	OB	2	(binary data)	
0002 0002	Media Storage SOP Class UID	UI	28	1.2.840.10008.5.1.4.1.1.1.1	SOP Class : Digital X-R
0002 0003	Media Storage SOP Instance UID	UI	46	1.2.840.113681.2162644097.6...	
0002 0010	Transfer Syntax UID	UI	18	1.2.840.10008.1.2	Transfer Syntax : Implic
0002 0012	Implementation Class UID	UI	16	1.2.804.114118.3	
0002 0013	Implementation Version Name	SH	6	eFilm	
0002 0016	Source Application Entity Title	AE	16		
0008 0000	Group Length	UL	4	852	
0008 0005	Specific Character Set	CS	10	ISO_IR 100	
0008 0008	Image Type	CS	18	DERIVED\PRIMARY\\IT	
0008 0016	SOP Class UID	UI	28	1.2.840.10008.5.1.4.1.1.1.1	SOP Class : Digital X-R
0008 0018	SOP Instance UID	UI	46	1.2.840.113681.2162644097.6...	
0008 0020	Study Date	DA	8	20020123	
0008 0021	Series Date	DA	8	20020123	
0008 0022	Acquisition Date	DA	8	20020123	
0008 0023	Image Date	DA	8	20020123	
0008 0030	Study Time	TM	6	170048	
0008 0031	Series Time	TM	6	170049	
0008 0032	Acquisition Time	TM	6	170331	
0008 0033	Image Time	TM	6	170331	
0008 0050	Accession Number	SH	8	20044731	
0008 0060	Modality	CS	2	DX	
0008 0068	Presentation Intent Type	CS	16	FOR PRESENTATION	
0008 0070	Manufacturer	LO	14	HOLOGIC, Inc.	
0008 0080	Institution Name	LO	36	Kaohsiung Veterans General Ho...	
0008 1060	Name of Physician(s) Reading...	PN	0		
0008 1070	Operators?Name	PN	8	HOLOGIC	
0008 1080	Admitting Diagnoses Description	LO	254	HISTORY OF COUGH , RHINOR...	
0008 1090	Manufacturer Model Name	LO	10	DROC2000I	
0008 2111	Derivation Description	ST	88	27,Chest PA PVH,2,3,2.0,1.0,0....	

Display issue 2

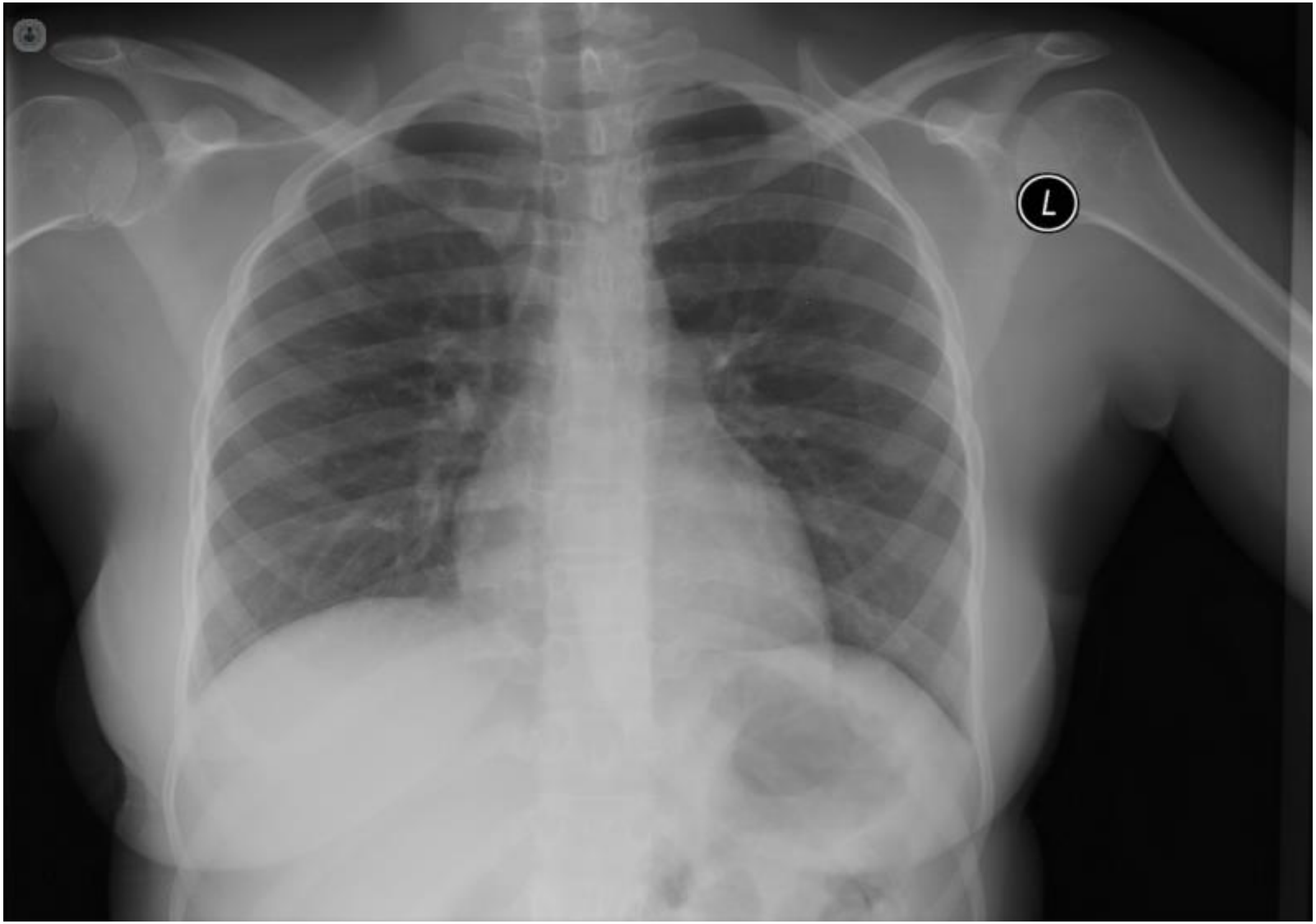
- Range of a normal 8-bit gray scale image: [0, 255]
- Image from CT scanner could be 12 bit.
- The pixel intensity of CT image is also called Hounsfield units.

Hounsfield Units for human body

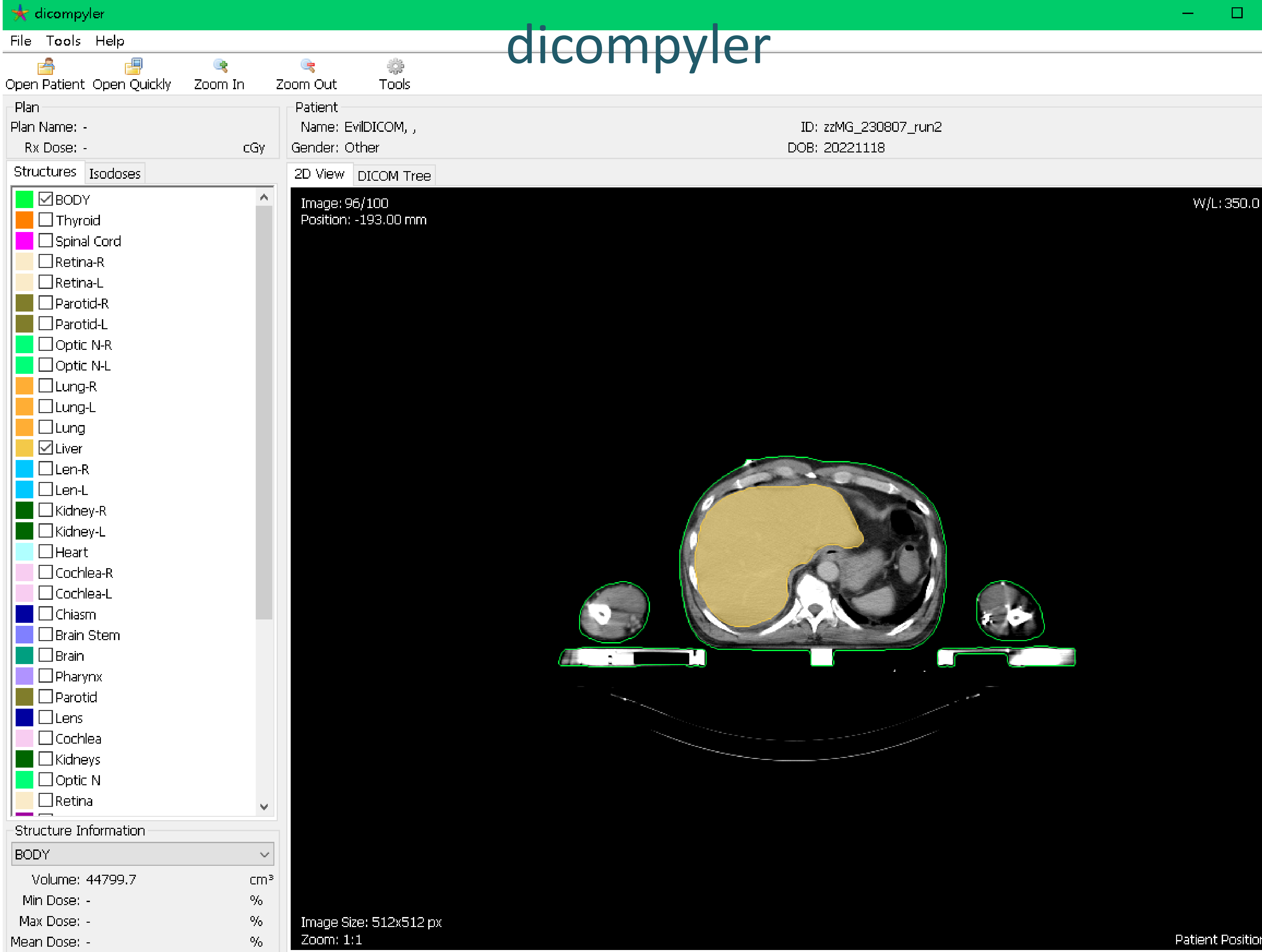
Bone	*1000*
Liver	*40 to 60*
White Matter	*46*
Grey Matter	*43*
Blood	*40*
Muscle	*10 to 40*
Kidney	*30*
Cerebrospinal Fluid	*15*
Water	*0*
Fat	*-50 to -100*
Air	*-1000*

Source of table: Backer et al. Combining MIMICS and Computational Fluid Dynamics (CFD) to assess the efficiency of a Mandibular Advancement Device (MAD) to treat Obstructive Sleep Apnea (OSA)

Example



dicompyler


dicompyler
File Tools Help
Open Patient Open Quickly Zoom In Zoom Out Tools
Plan
Plan Name: -
Rx Dose: - cGy
Patient
Name: EvilDICOM, ,
ID: zzMG_230807_run2
Gender: Other
DOB: 20221118
Structures Isodoses
2D View DICOM Tree
BODY
Thyroid
Spinal Cord
Retina-R
Retina-L
Parotid-R
Parotid-L
Optic N-R
Optic N-L
Lung-R
Lung-L
Lung
Liver
Len-R
Len-L
Kidney-R
Kidney-L
Heart
Cochlea-R
Cochlea-L
Chiasm
Brain Stem
Brain
Pharynx
Parotid
Lens
Cochlea
Kidneys
Optic N
Retina
Structure Information
BODY
Volume: 44799.7 cm³
Min Dose: - %
Max Dose: - %
Mean Dose: - %
Image: 96/100
Position: -193.00 mm
W/L: 350.0 /
Image Size: 512x512 px
Zoom: 1:1
Patient Position:

Another format: NIfTI

NIfTI (Neuroimaging Informatics Technology Initiative) format is a widely used standard data format in medical imaging research for storing and sharing neuroimaging data, particularly in brain studies. The developmental history of the NIfTI format is as follows:

1. Limitations of DICOM Format: In the early days of medical imaging research, data was primarily stored using the DICOM format. However, DICOM format focused on image transmission and storage, making it less suitable for complex image analysis and processing.
2. Issues with ANALYZE Format: Apart from DICOM, some brain research communities used the ANALYZE format for data storage. However, this format had drawbacks such as an inability to handle large datasets, undefined header information, and data type issues.

Another format: NIfTI

3. Birth of NIfTI: Due to the needs of medical imaging research, the development of the NIfTI format began in the late 1990s. The format aimed to address the issues of the ANALYZE format while providing a structured data format better suited for analysis. The basic idea of the NIfTI format was to store image data as two files: one containing header information (.hdr file) and another containing the actual image data (.img file).

(You can decompress the file 'nifti_avg152t1_lr.img.zip'

4. NIfTI-1 and NIfTI-2: The initial NIfTI format was called NIfTI-1, released in 2004, quickly becoming the standard format for brain imaging research. Later, with technological advancements and changing demands, the NIfTI-2 format was introduced in 2017. Building upon NIfTI-1, NIfTI-2 expanded support for more data types and attributes.

Another format: NIfTI

5. Development and Applications: The NIfTI format found widespread applications in the field of medical imaging research. It provided researchers and software developers with a unified data format, facilitating data sharing, diverse analysis techniques, and collaboration. Many image processing software, statistical tools, and brain research utilities support the NIfTI format, further driving its development and adoption.

To read NIfTI file (*.nii) in python, install 'NiBabel'

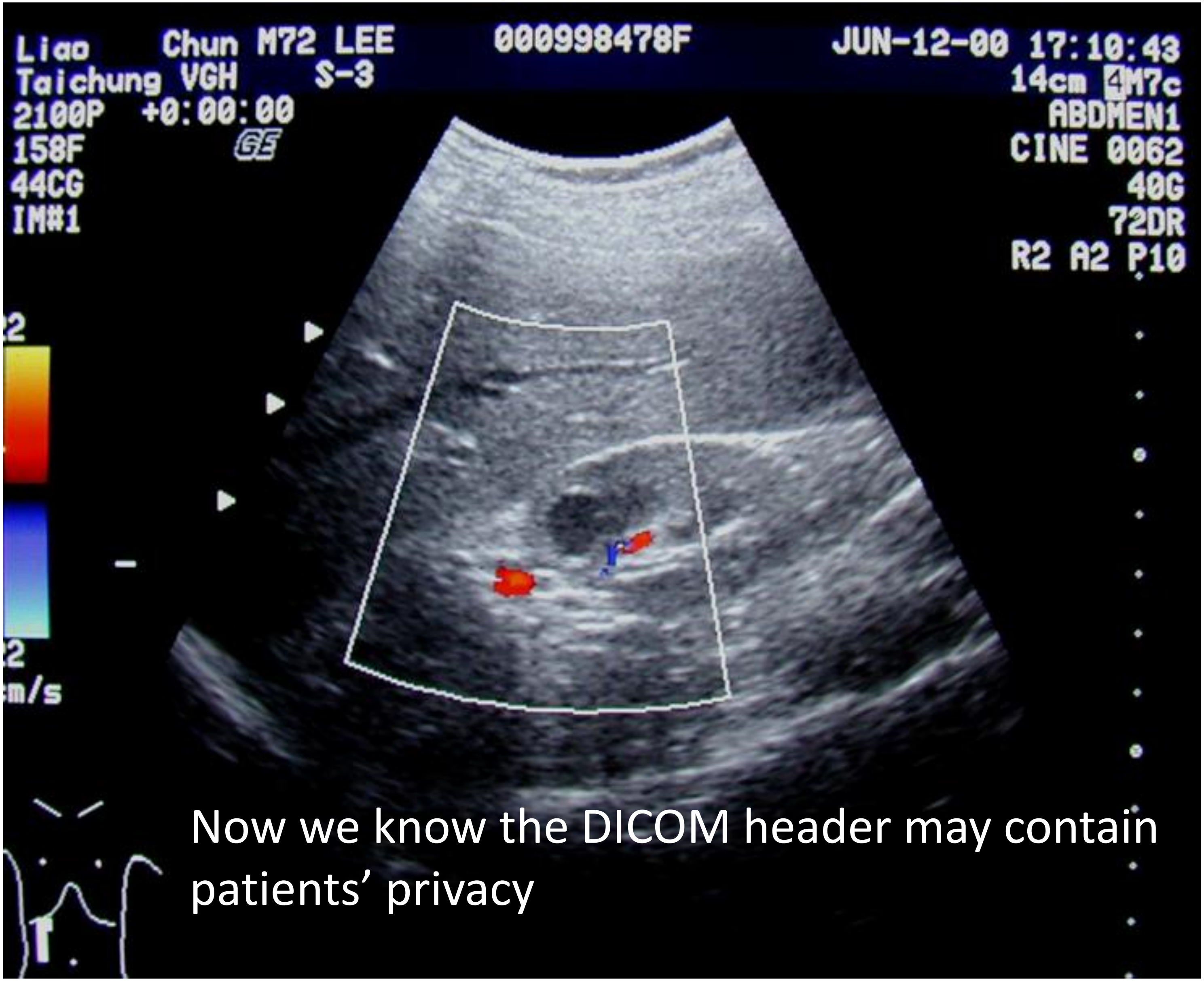
Example in Chinese: https://officeguide.cc/python-nibabel-read-show-nifti-image-tutorial-examples/

```python
import os
import nibabel as nib
from nibabel.testing import data_path

# 取得 NIfTI 1 範例影像路徑
example_ni1 = os.path.join(data_path, 'example4d.nii.gz')

# 載入 NIfTI 1 範例影像
n1_img = nib.load(example_ni1)

# 顯示 NIfTI 1 範例影像標頭資訊
print(n1_img.header)
```

The header file of NIfTI format focuses more on the properties of image content.

```
<class 'nibabel.nifti1.Nifti1Header'> object, endian='<'
sizeof_hdr      : 348
data_type       : b''
db_name         : b''
extents         : 0
session_error   : 0
regular         : b'r'
dim_info        : 57
dim             : [  4 128  96  24   2   1   1   1]
intent_p1       : 0.0
intent_p2       : 0.0
intent_p3       : 0.0
intent_code     : none
datatype        : int16
bitpix          : 16
slice_start     : 0
pixdim          : [-1.000000e+00  2.000000e+00  2.000000e+00  2.199999e+00  2.000000e+03
  1.000000e+00  1.000000e+00  1.000000e+00]
vox_offset      : 0.0
scl_slope       : nan
scl_inter       : nan
slice_end       : 23
slice_code      : unknown
xyzt_units      : 10
cal_max         : 1162.0
cal_min         : 0.0
slice_duration  : 0.0
toffset         : 0.0
glmax           : 0
glmin           : 0
descrip         : b'FSL3.3\x00 v2.25 NIfTI-1 Single file format'
aux_file        : b''
qform_code      : scanner
sform_code      : scanner
quatern_b       : -1.9451068e-26
quatern_c       : -0.9967085
quatern_d       : -0.08106874
qoffset_x       : 117.8551
qoffset_y       : -35.722942
qoffset_z       : -7.2487984
srow_x          : [-2.0000000e+00  6.7147157e-19  9.0810245e-18  1.1785510e+02]
srow_y          : [-6.7147157e-19  1.9737115e+00 -3.5552824e-01 -3.5722942e+01]
srow_z          : [ 8.2554809e-18  3.2320762e-01  2.1710818e+00 -7.2487984e+00]
intent_name     : b''
magic           : b'n+1'
```

Data anonymization



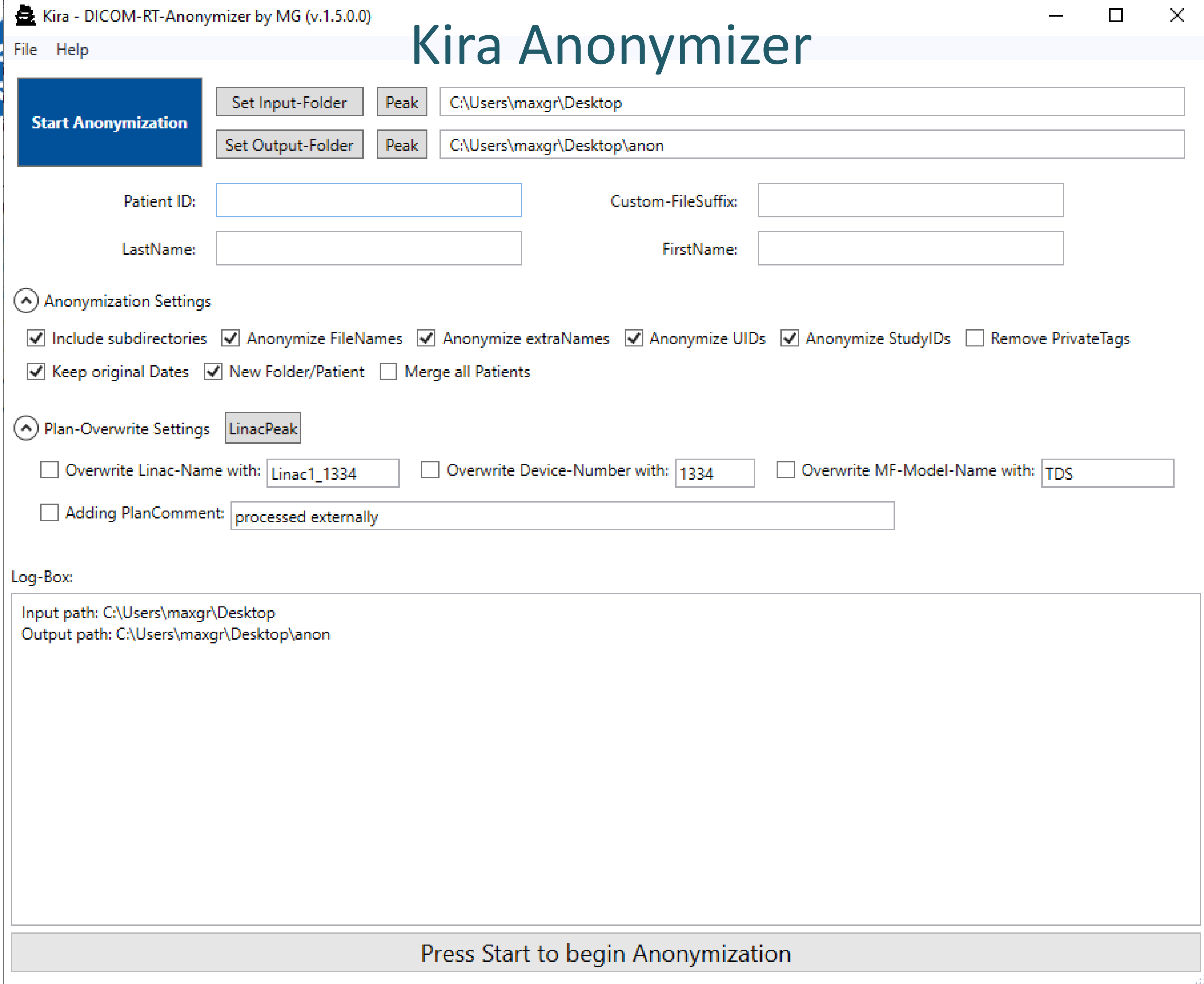
Now we know the DICOM header may contain patients' privacy

When you receive data from doctors…

1. Check the DICOM header
2. If it contains patient information, share it with caution.
3. Remove patient info by Kira anonymizer.
4. Personal identification information is protected by law.

0008,1030)	StudyDescription	
0008,103E)	SeriesDescription	Abdomen C+ 5.0 eFoV
0008,1040)	InstitutionalDepartmentName	Anonymized
0008,1090)	ManufacturerModelName	Emotion 6 (2007)
0010,0010)	PatientName	EvilDICOM
0010,0020)	PatientID	zzMG_230807_run2
0010,0030)	PatientBirthDate	20221118
0010,0040)	PatientSex	
0018,0015)	BodyPartExamined	ABDOMEN
0018,0050)	SliceThickness	5
0018,0060)	KVP	130
0018,1020)	SoftwareVersions	Version 4.9.2
0018,5100)	PatientPosition	HFS
0020,000D)	StudyInstanceUID	1.2.345.678.98.20191003181
0020,000E)	SeriesInstanceUID	1.2.543.876.89.20191003181
0020,0010)	StudyID	CT_1

Kira Anonymizer



Part 2

Segmentation examples

Outline

- Image segmentation
- AI developed for poly delineation in colonoscopy
- AI developed for organ delineation in CT images
- Conclusion

Image segmentation

What is image segmentation?

[wiki]

1. Partition an image into multiple image segments, also known as image regions or image objects (sets of pixels).
2. Locate objects and boundaries (lines, curves, etc.) in images.
3. Assign a label to every pixel in an image such that pixels with the same label share certain characteristics.
4. Goal: simplify the representation of an image into something that is more meaningful and easier to analyze.

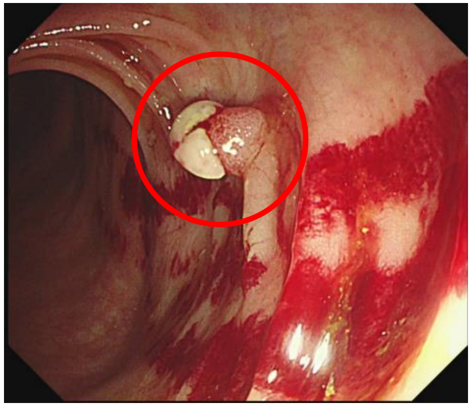
Segmentation methods

1. Thresholding
2. Clustering methods
3. Motion and interactive segmentation
4. Compression-based methods
5. Edge detection
6. Dual clustering method
7. Region-growing methods
8. Partial differential equation-based methods
9. Graph partitioning methods
10. Watershed transformation

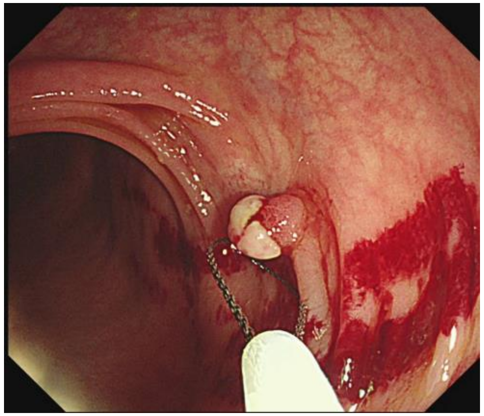
Colonoscopy

- Age-standardized incidence rates (ASIR) for colon cancer in 2014
  - Taiwan: 44.7 / 100,000 (No. 1)
  - India: 6.9 / 100,000
- Preventive strategy: the physicians look for colon polyps visually through the colonoscopy exam. A standard exam usually takes 10-30 minutes.
- When an abnormal polyp is found, it should be excised immediately to prevent cancer development.
- Nonneoplastic: hyperplastic, inflammatory, hamartomatous ➔typically do not become cancerous.
- Neoplastic: adenomas and serrated types

  ➔potential to become cancer if given enough time to grow



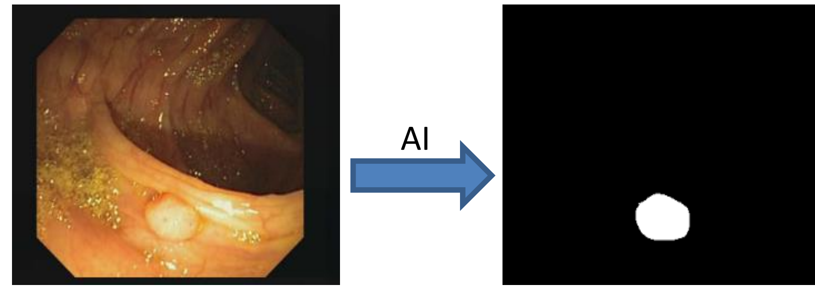
Polyp found in colonoscopy



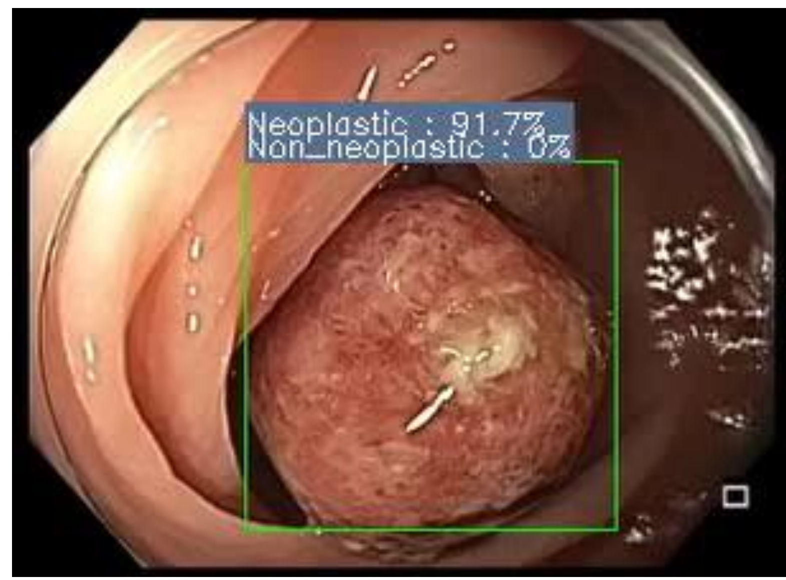
Excising a polyp

Our solution

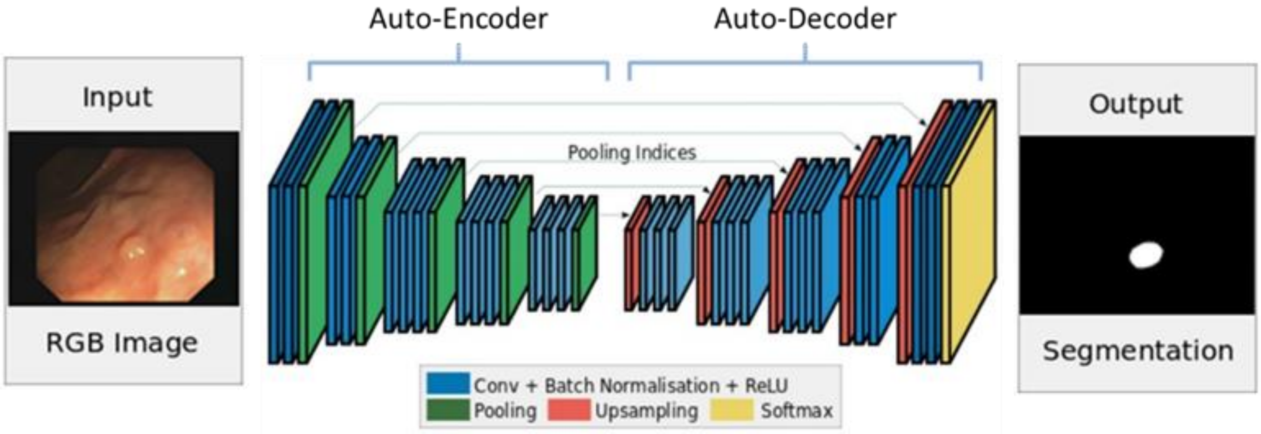
- Apply deep learning to build a computer-aided segmentation and classification system.
- It locates the colorectal polyps from the background with normal tissue and uneven inner structure in real-time during a traditional colonoscopy exam.
- In the output mask: probability estimation of neoplastic v.s nonneoplastic polyps



Input Output

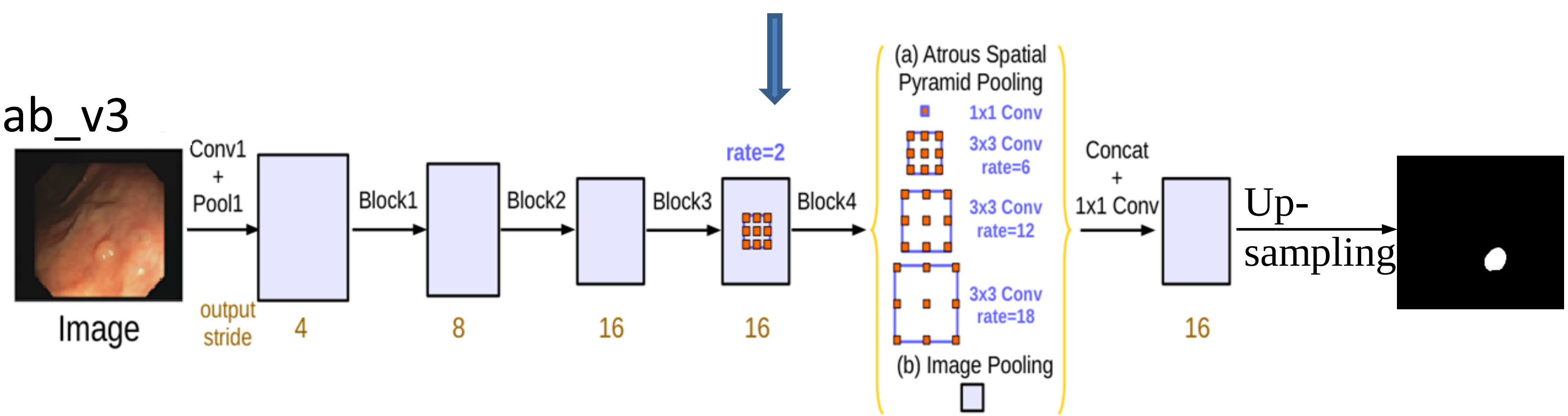


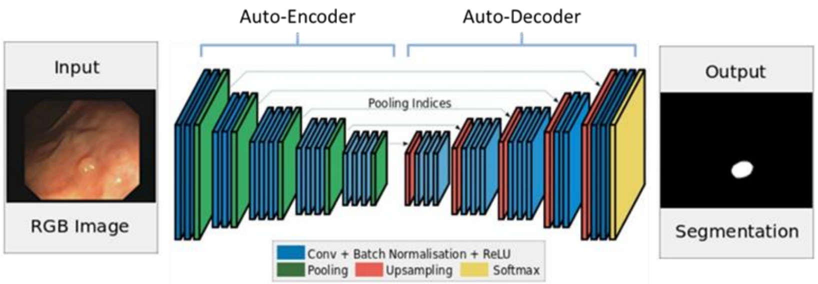
SegNet

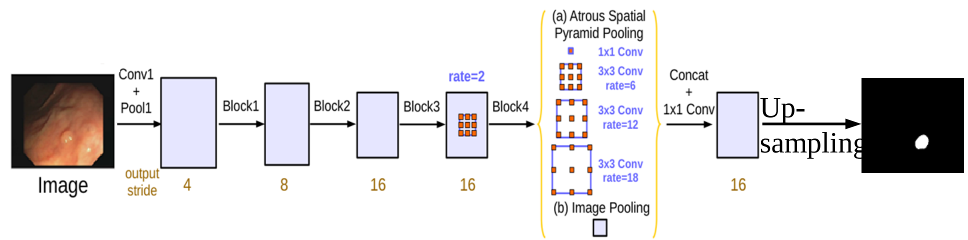


1. After multiple layers of conv./pooling, the resolution of feature maps are getting lower, which degrades the image reconstruction in decoder.
2. The detection performance is also unstable when the size of targets varies.

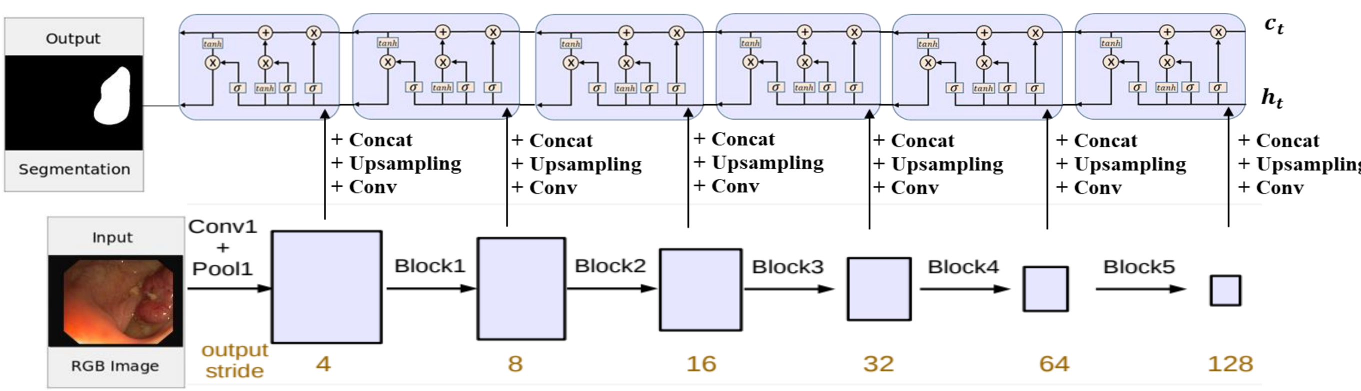
Deeplab_v3







Both SegNet and Deeplab_v3 are computationally intensive, and may cause delay when displaying the segmentation results in real time.



The exam room could be spacious or small, when at least one doctor and one nurse perform the exam.

Results

- Operating System : Ubuntu 16.04
- Video Graphics card : Nvidia GTX 1080
- **Colonoscopy Database** : CVC – EndoSceneStill (public)

	Database	Resolution	Image for training	Data Augmentation	Images for validation	Images for testing
CVC – EndoSceneStill	CVC-ClinicDB	384 x 288	367	x4 = 1468	60	60
	CVC-ColonDB	500 x 574	180	x9 = 1620	123	122

- Good performance, less computation

Method	Accuracy	Sensitivity	Specificity	F1-score	Time per image
SegNet	95.63 %	48.61 %	99.28 %	61.59 %	55 ms
Our Network	95.86 %	**58.57 %**	98.76 %	67.13 %	**45 ms**
DeepLab	**96.31 %**	55.26 %	**99.51 %**	**68.38 %**	64 ms

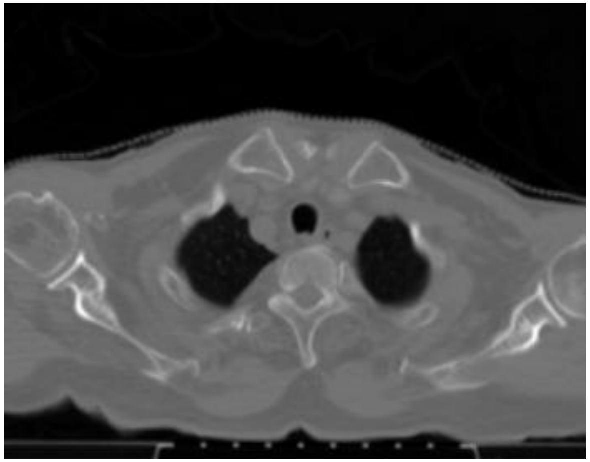
The problem is…

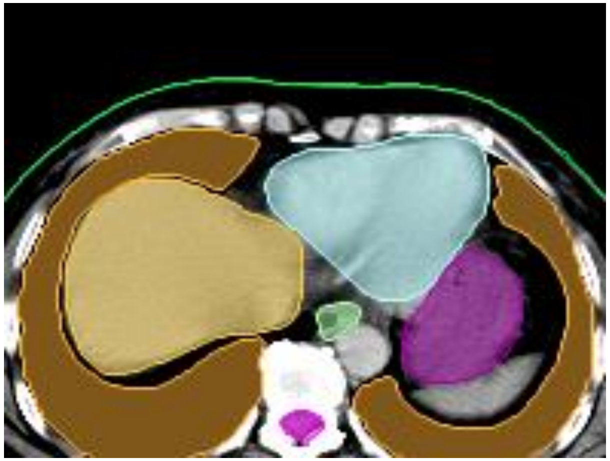
It looks cool ， but it's not needed

圖片均取自於網路

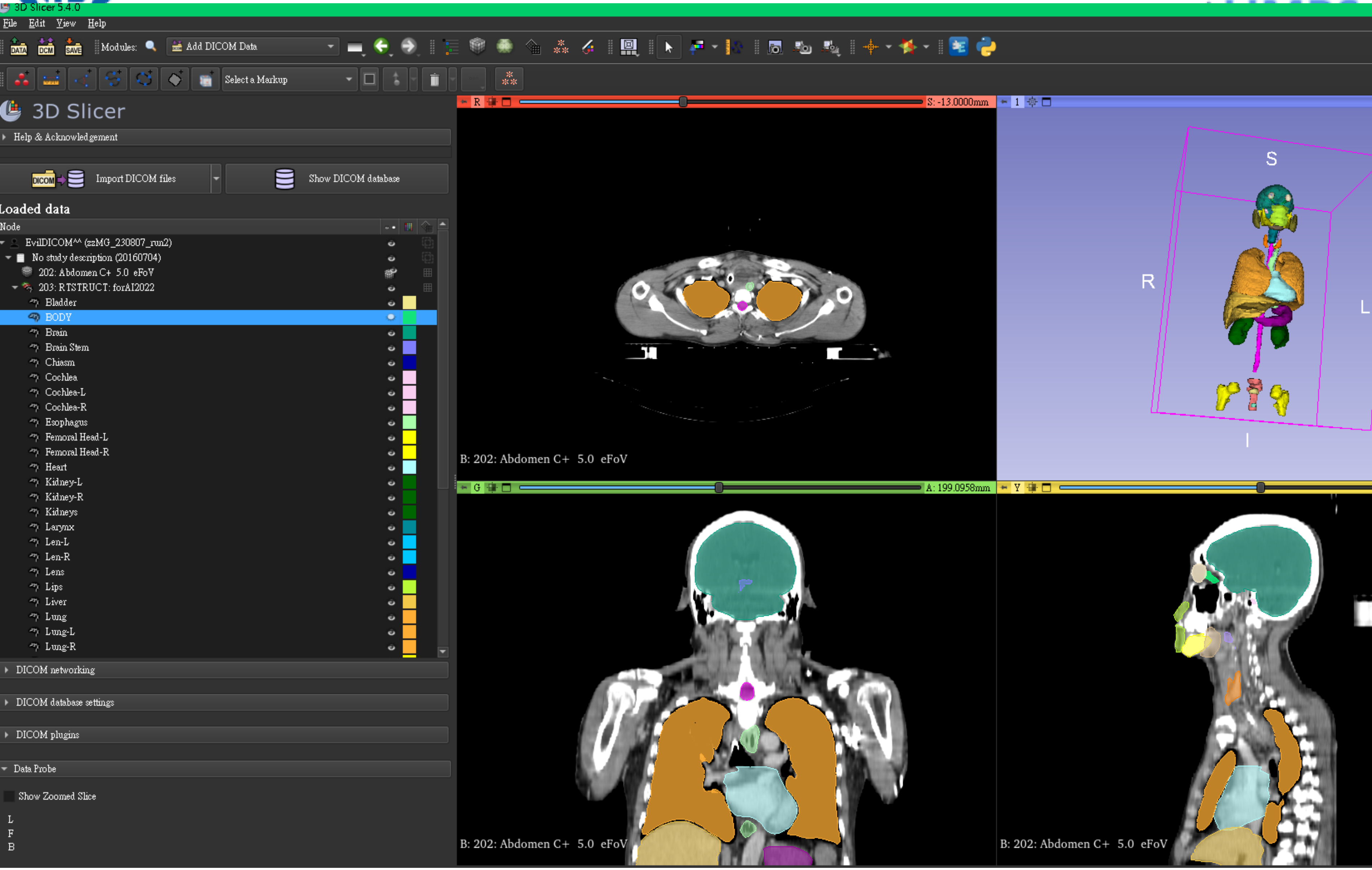
Organ delineation / contouring

- CT scan is performed prior to the radiotherapy.
- It takes an hour to finish the delineation over the whole CT scan.
- The software uses the boundaries to calculates the incidence path and angle.
- Delineation is not a one-time task. A tumor needs several times of radiotherapy. The shapes of patient's organs or body may also change during the treatment.





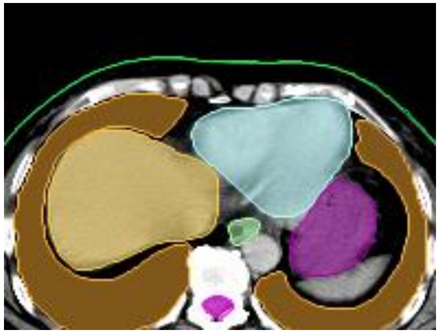
3D Slicer


3D Slicer 5.4.0
File Edit View Help
Modules:
Add DICOM Data
Select a Markup
3D Slicer
Help & Acknowledgement
Import DICOM files
Show DICOM database
Loaded data
Node
EvilDICOM^^ (zzMG_230807_run2)
No study description (20160704)
202: Abdomen C+ 5.0 eFoV
203: RTSTRUCT: forAI2022
Bladder
BODY
Brain
Brain Stem
Chiasm
Cochlea
Cochlea-L
Cochlea-R
Esophagus
Femoral Head-L
Femoral Head-R
Heart
Kidney-L
Kidney-R
Kidneys
Larynx
Len-L
Len-R
Lens
Lips
Liver
Lung
Lung-L
Lung-R
DICOM networking
DICOM database settings
DICOM plugins
Data Probe
Show Zoomed Slice
L
F
B
R
S: -13.0000mm
B: 202: Abdomen C+ 5.0 eFoV
1
S
R
L
I
G
A: 199.0958mm
Y

RT structure set

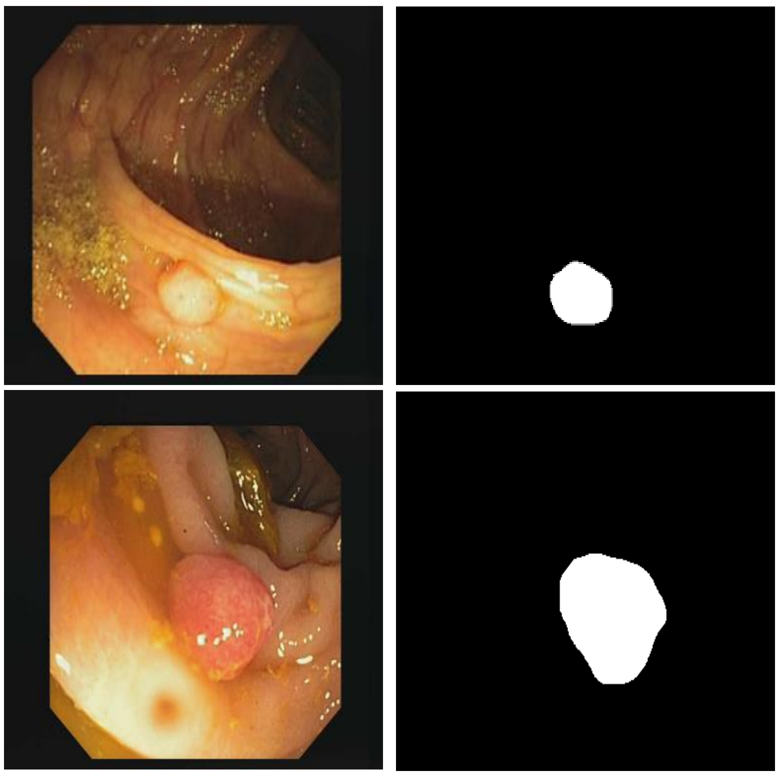
CT.1.2.840.35235.20191003181002014288178861899518726087 41.91.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.92.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.93.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.94.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.95.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.96.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.97.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.98.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.99.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
CT.1.2.840.35235.2019100318100201428817886189951872608741.100.dcm	2023/8/18 下午 04:09	IrfanView DCM File	514 KB
RS.1.2.246.352.205.547526631193823677614204613592314173349.dcm	2023/8/18 下午 04:09	IrfanView DCM File	3,913 KB

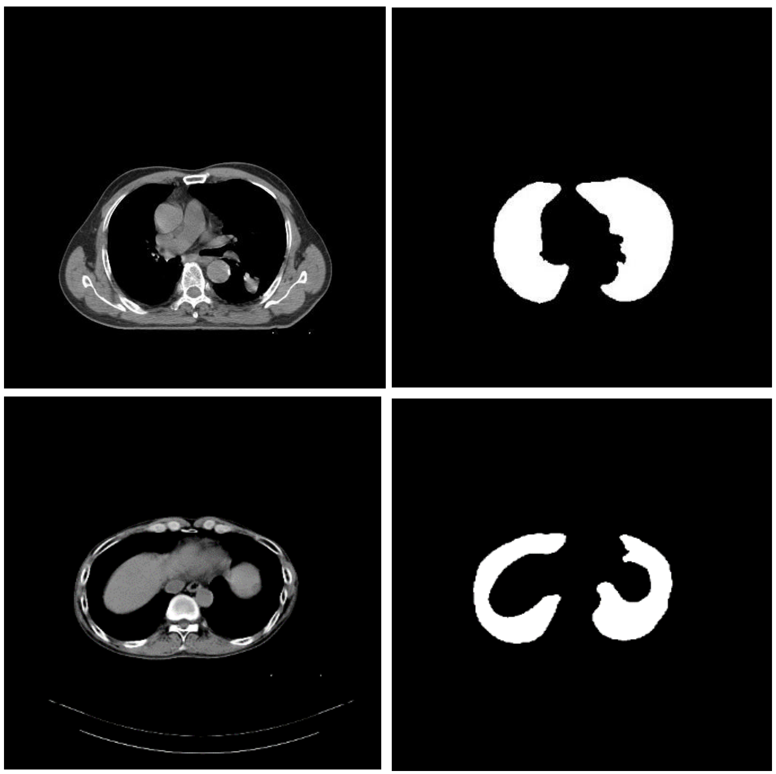
- DICOM_RT = pydicom.dcmread(RT_filename)
- The contour is actually formed by a set of pixels, not a mask.
- The mask should be generated by ourselves.



From colonoscopy to CT scan

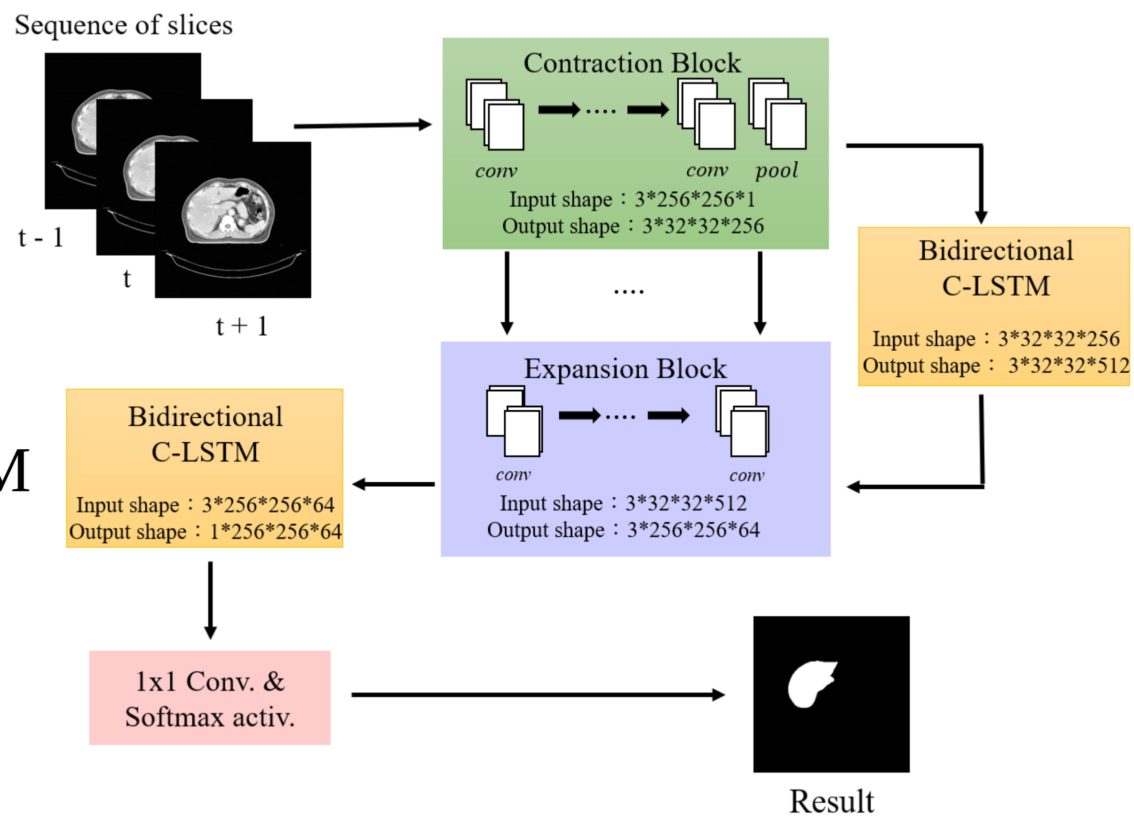
The shape of organs varies more than the one of polyps, so the organ delineation is a more challenging task.





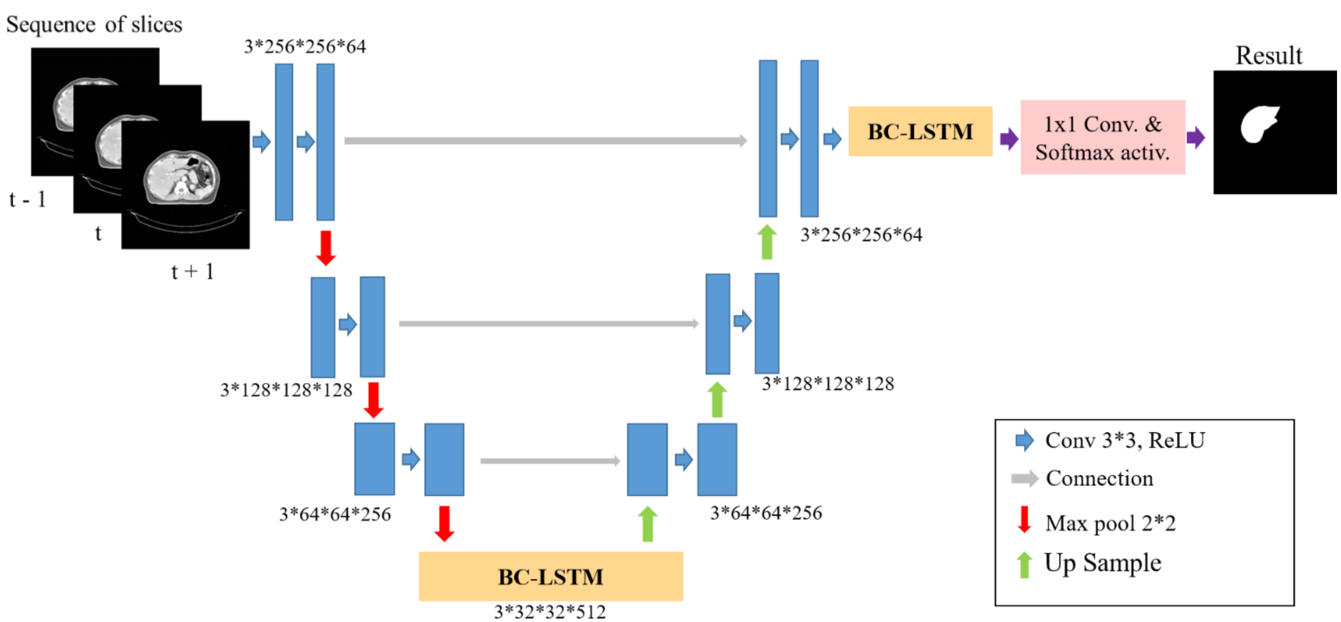
Sensor3D

- Contain 3 blocks
  1. Contraction Block
  2. Expansion Block
  3. Bidirectional C-LSTM

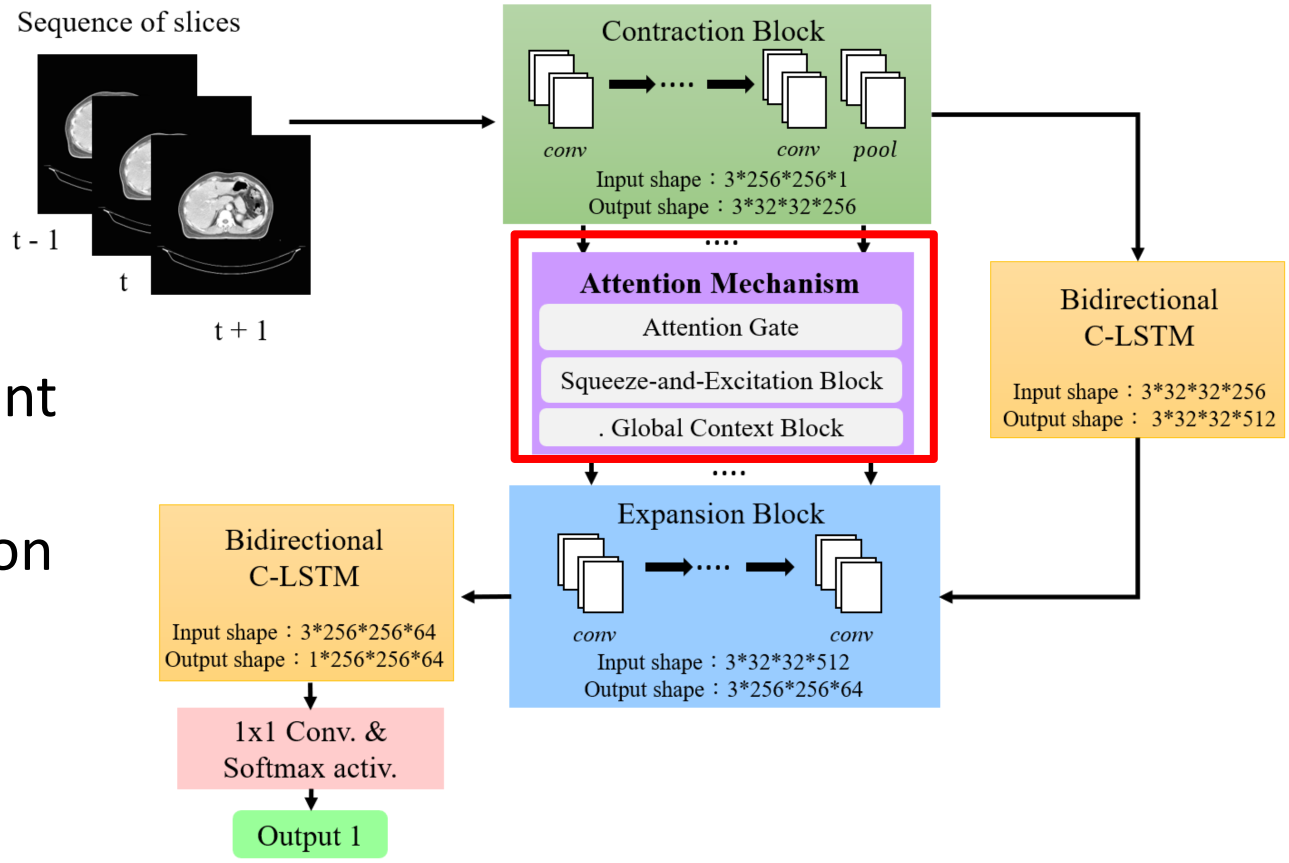


Sensor3D

- Contraction Block：3 times of 3*3 Conv. Layer and ReLU, a 2*2 max pooling Layer
- Expansion Block：3 times of upsampling, 3*3 Conv. Layer and ReLU
- Like the contracting path and expansive path of U-net，retain the skip-connection



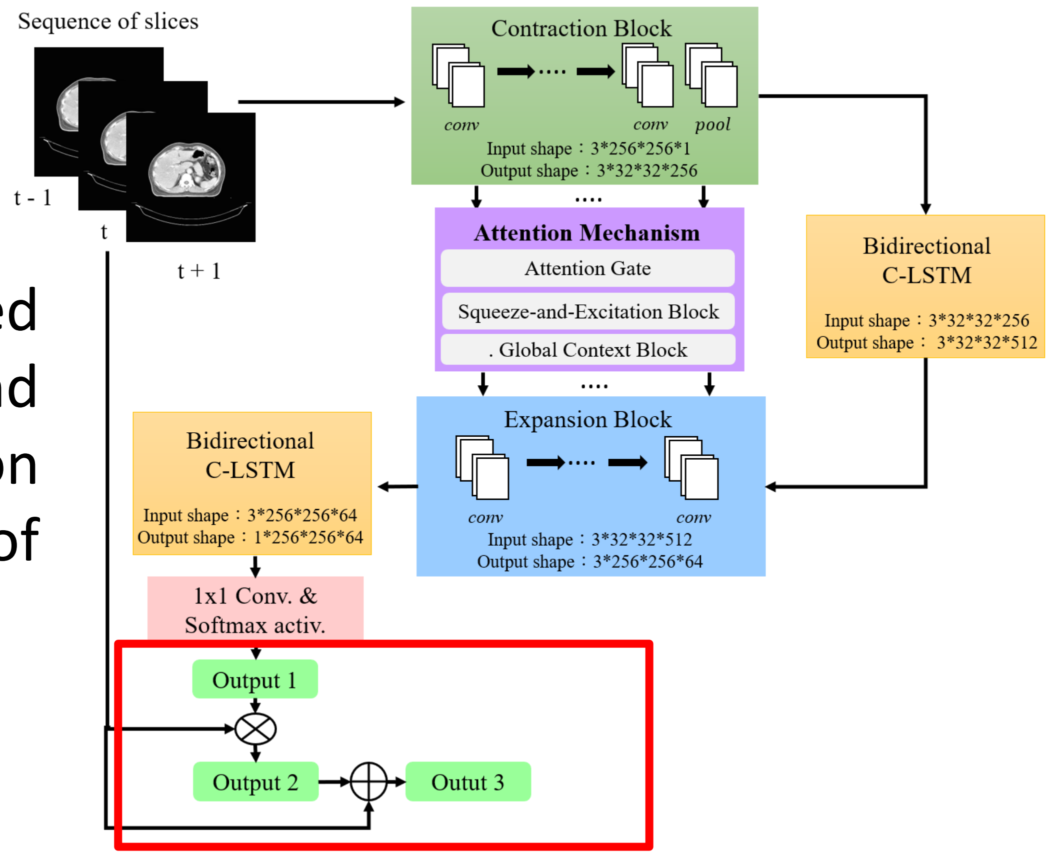
Sensor3D and U-Net with Attention Block



We investigated different Attention Mechanisms between the Contraction and Expansion Blocks.

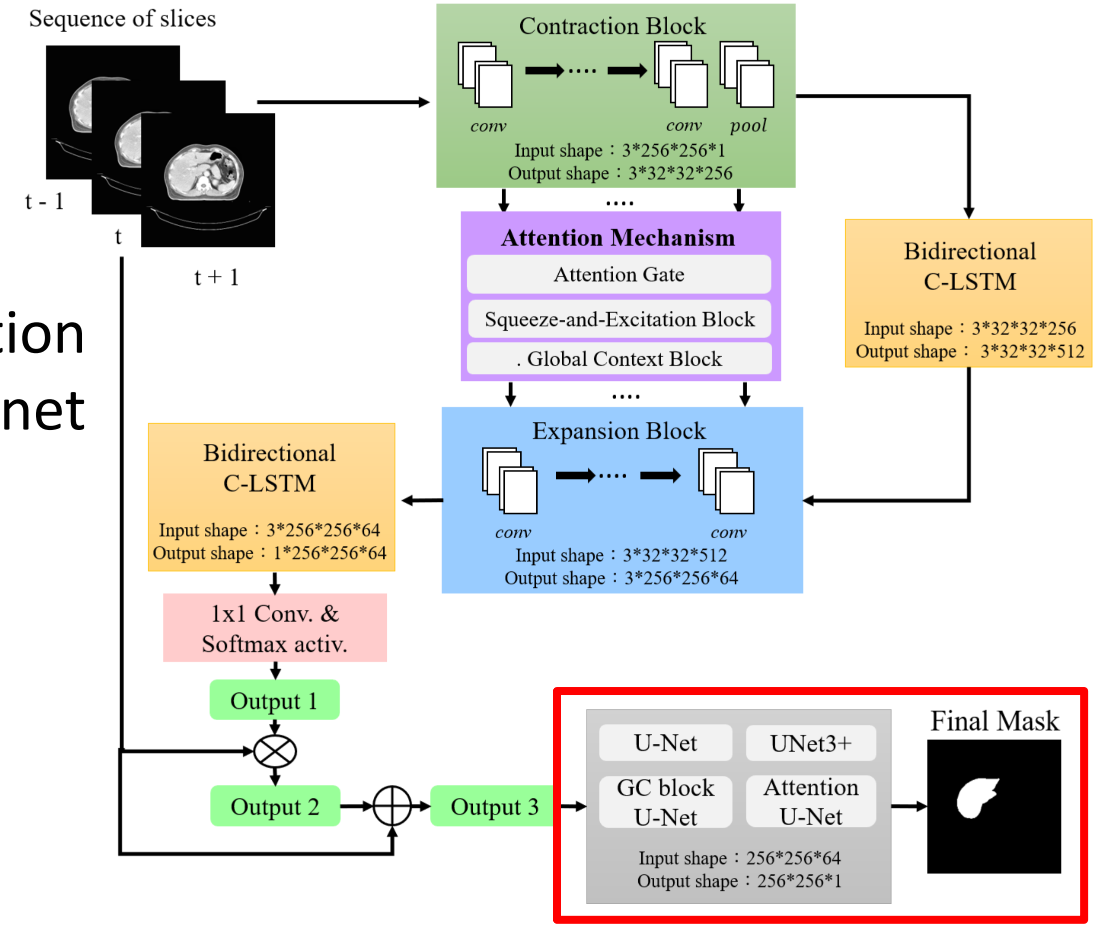
Sensor3D and U-Net with Attention Block

The input CT images is weighted by its initial segmentation, and consider this as an attention map for next round of segmentation.



Sensor3D and U-Net with Attention Block

Second round of segmentation can be performed by U-net based networks.

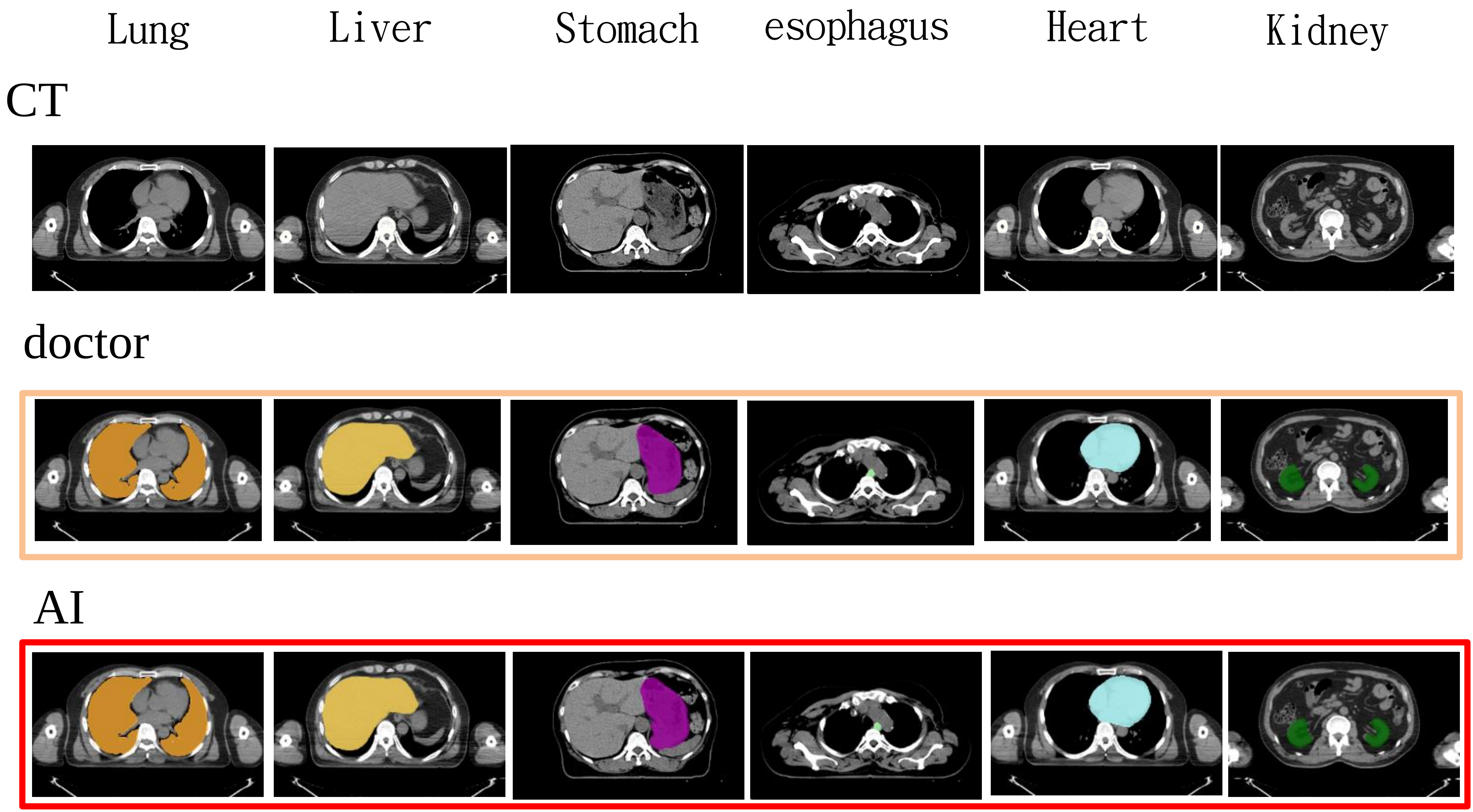


Datasets

Size of dataset to train the models:

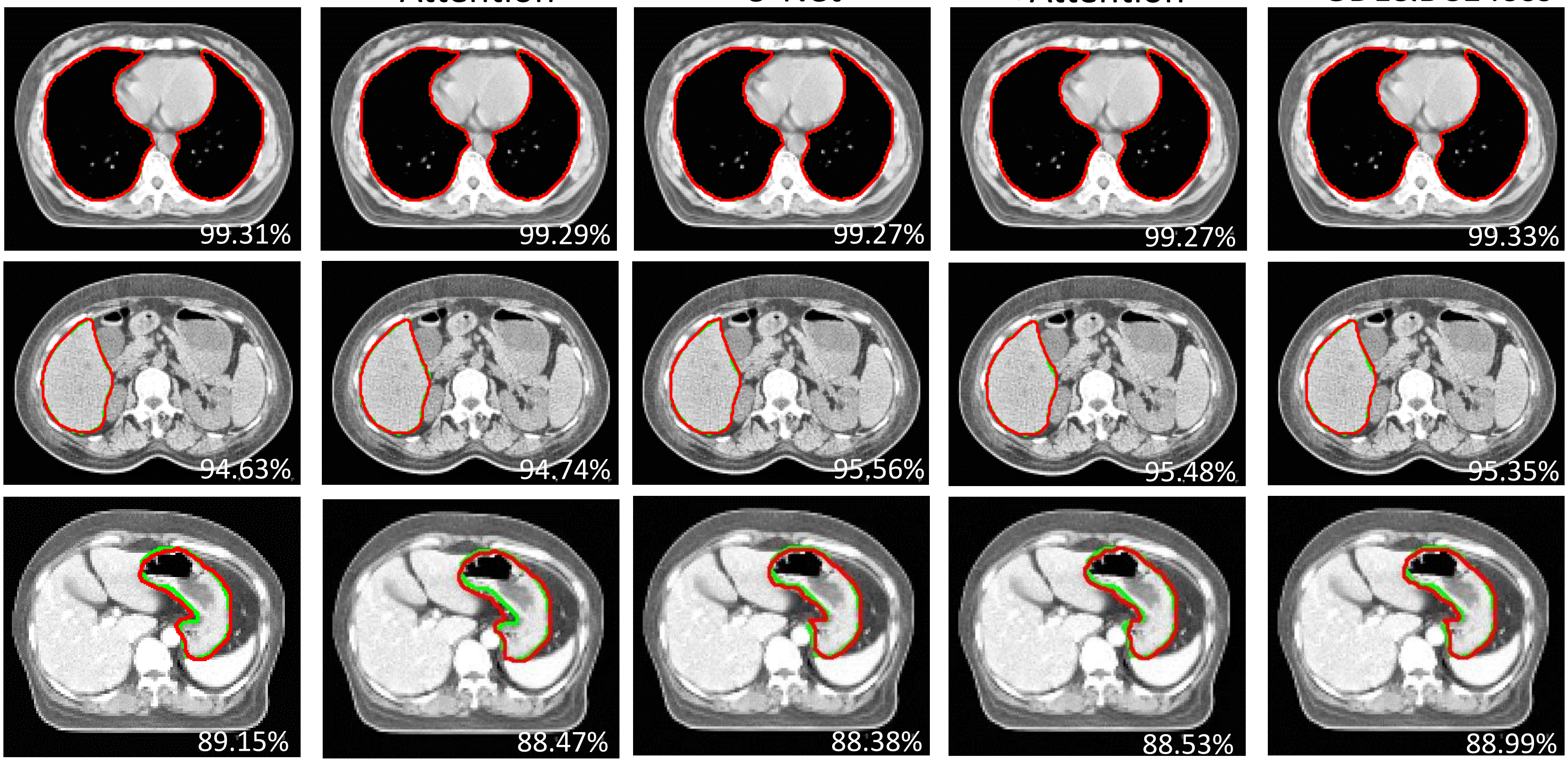
Organ	Training dataset	Testing dataset
Lung	60 cases，6598 CT images	18 cases，1881 CT images
Liver	82 cases，8662 CT images	5 cases，628 CT images
Stomach	69 cases，7041 CT images	3 cases，355 CT images
Esophagus	40 cases，4643 CT images	15 cases，1644 CT images
Heart	50 cases，5631 CT images	20 cases，2105 CT images

Comparison

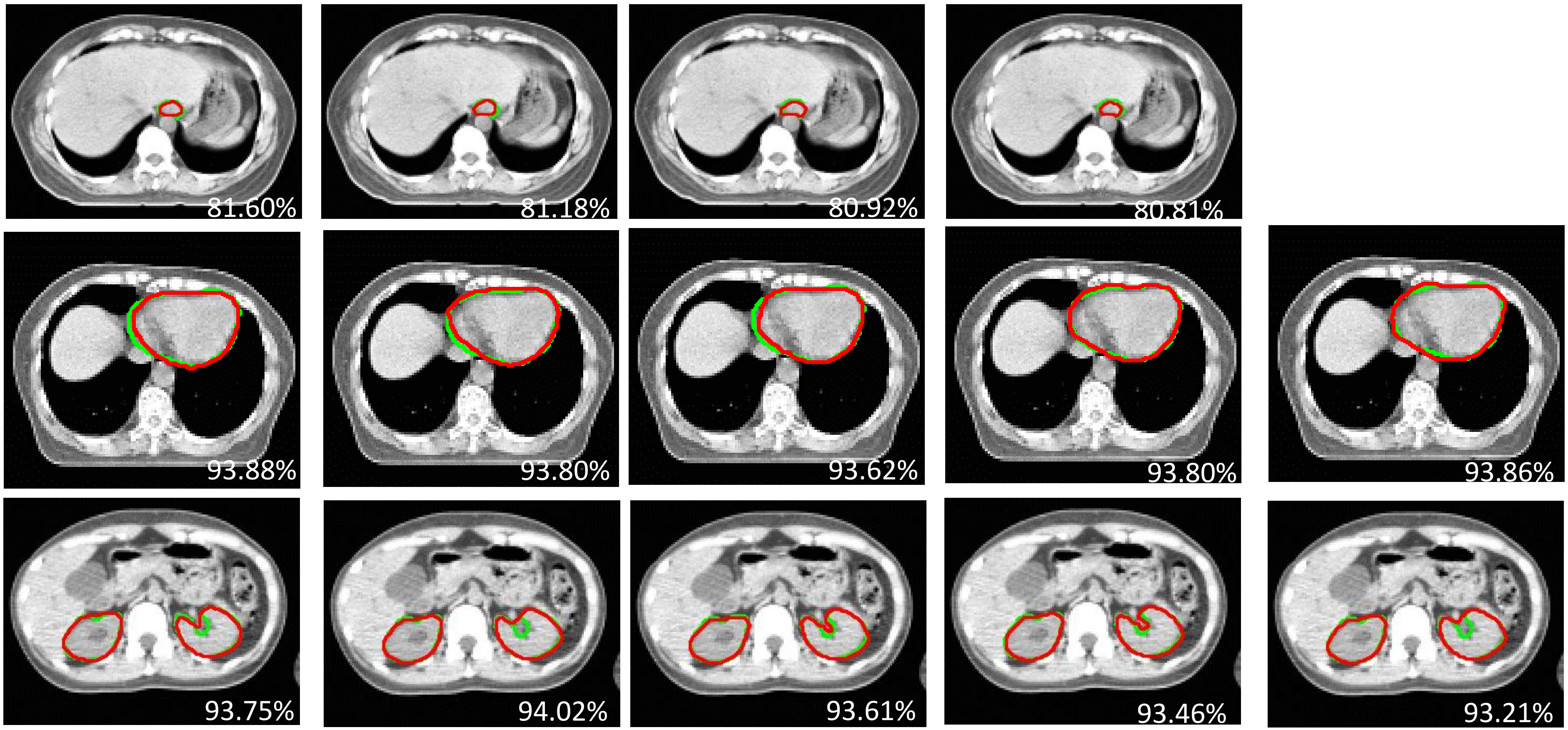


Organ \ Networks	Sensor3D	Sensor3D +Attention	Sensor3D +U-Net	Sensor3D + U-Net +Attention	Sensor3D + U-Net +Attention + GDL&BCE loss
Lung	99.31%	99.29%	99.27%	99.27%	**99.33%**
Liver	94.63%	94.74%	**95.56%**	95.48%	95.35%
Stomach	**89.15%**	88.47%	88.38%	88.53%	88.99%
Esophagus	**81.60%**	81.18.%	80.92%	80.81%	-
Heart	**93.88%**	93.80%	93.62%	93.80%	93.86%
Kidney	93.75%	**94.02%**	93.61%	93.46%	93.21%

Sensor3D	Sensor3D +Attention	Sensor3D +U-Net	Sensor3D + U-Net +Attention	Sensor3D+ U-Net +Attention + GDL&BCE loss

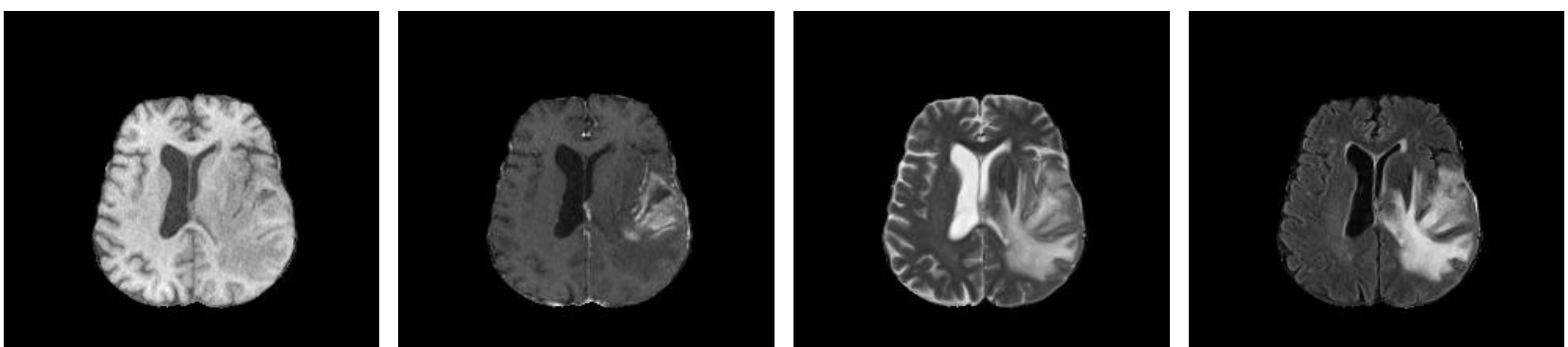


Sensor3D	Sensor3D +Attention	Sensor3D +U-Net	Sensor3D + U-Net +Attention	Sensor3D+ U-Net +Attention + GDL&BCE loss



Tumor segmentation in brain MRI

- Glioma is the most common primary brain tumor of the brain, and the main treatment methods are surgery and radiation therapy.
- Its boundary is blurred and difficult to demarcate, its size, shape, and location are not fixed, and its appearance is similar to that of glial degeneration, stroke, and inflammation on MRI.
- Treatment planning for radiation therapy requires precise tumor contours

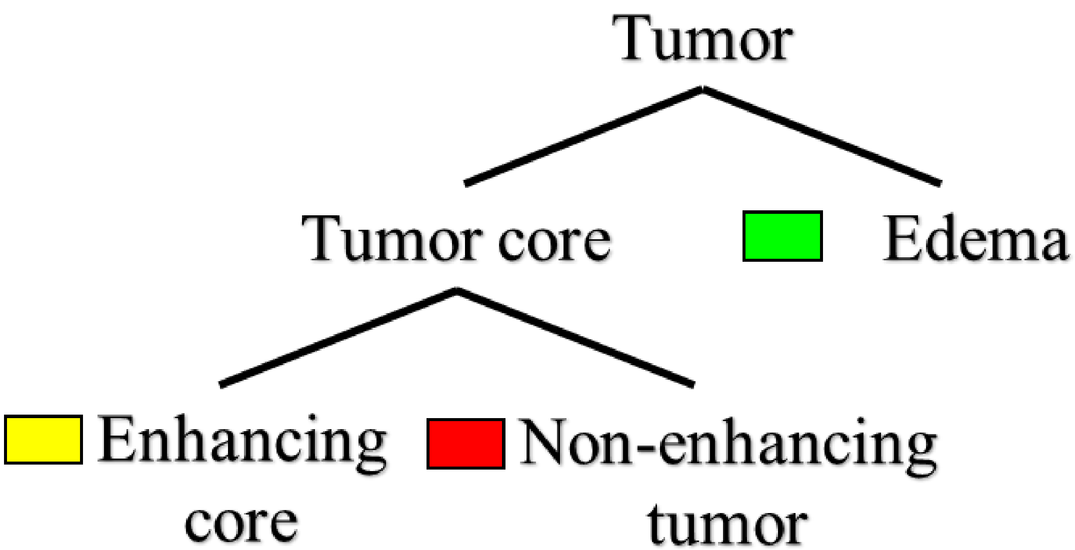


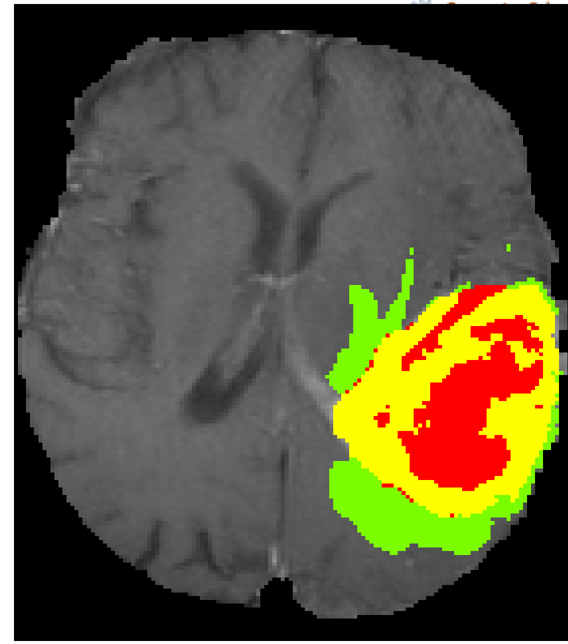
Dataset

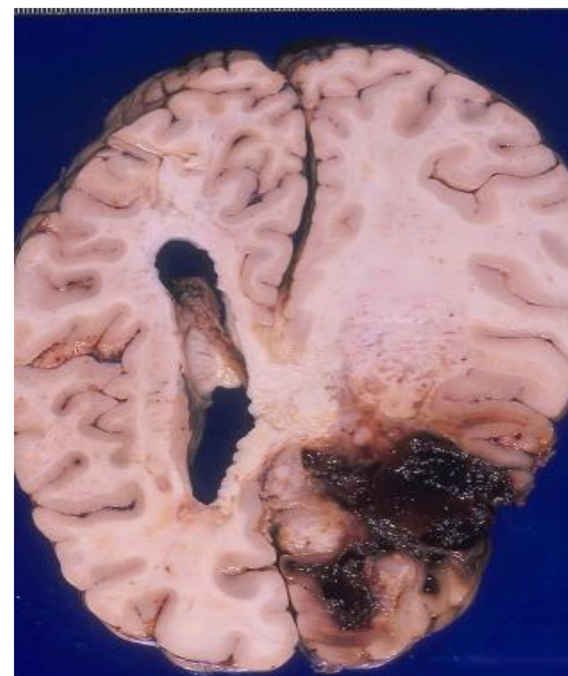
- BraTS 2019 challenge hosted by Univ. of Pennsylvania, school of medicine.
- 335 cases for training (259 patients with high-grade gliomas and 59 patients with low-grade gliomas)。
- 4 sequences: T1、T1ce、T2、Flair。
- NifTI format。
- Image size: 240×240。
- Each scan contains 155 slices。
- Tissue classification: Enhancing core, Non-enhancing tumor, Edema。

Dataset

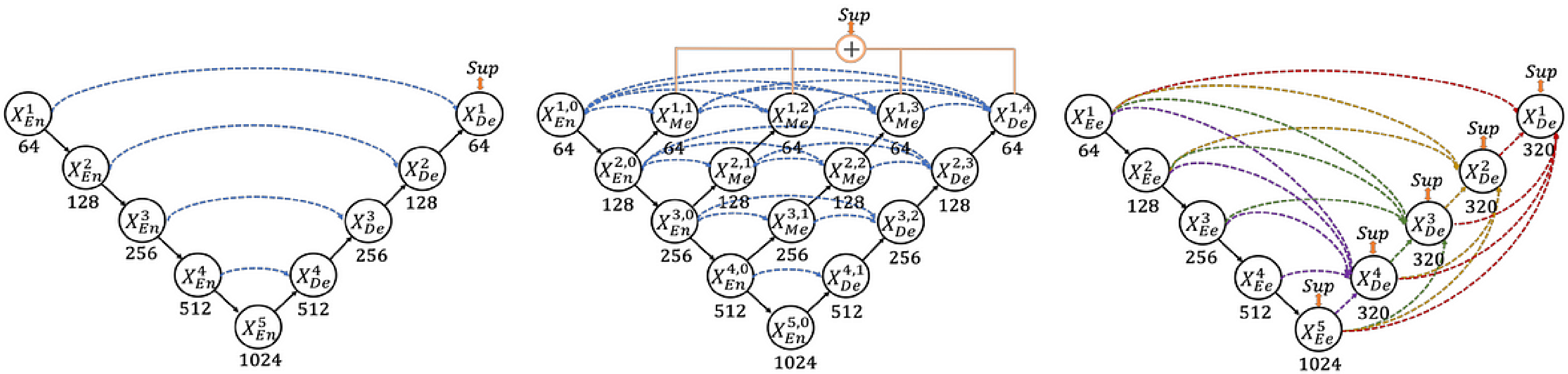
- Labels in BraTS 2019







Segmentation model & Attention module

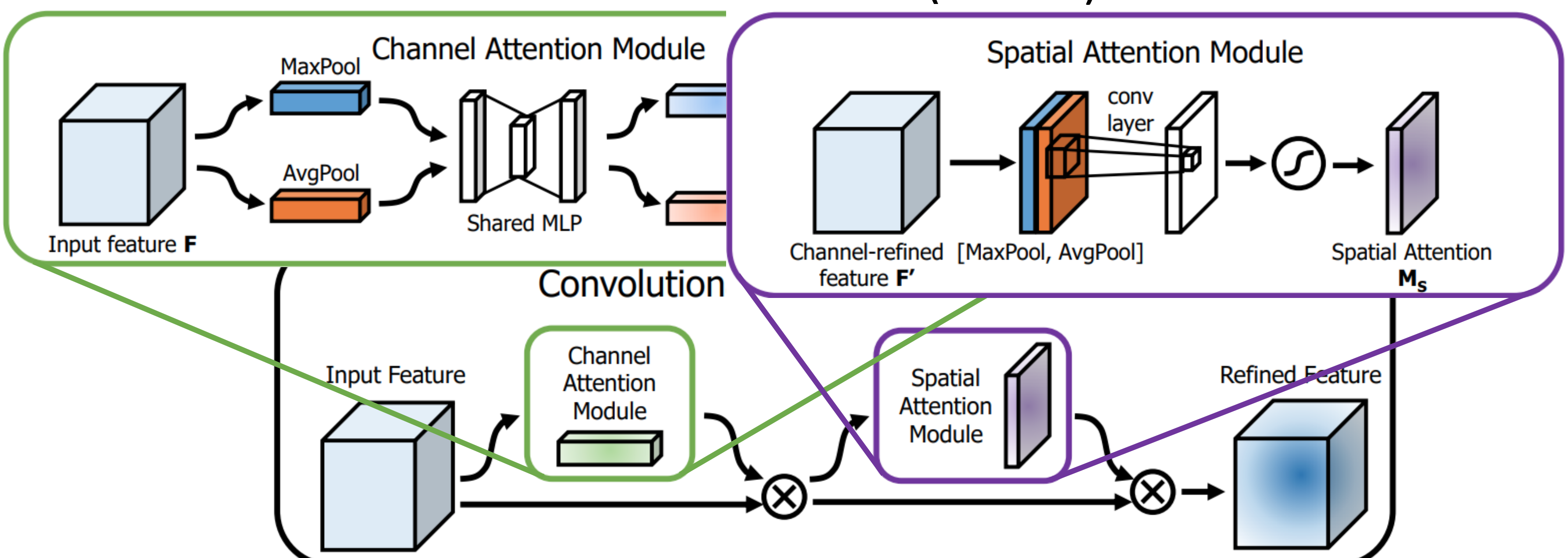


(a) UNet
(Plain skip connections)

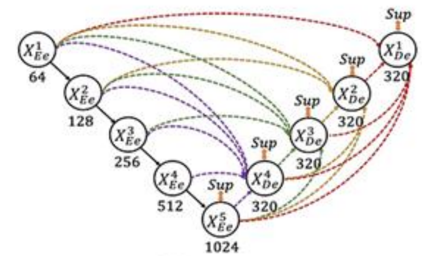
(b) UNet++
(Nested and dense skip connections)

(c) UNet 3+
(Full-scale skip connections)

- Convolutional Block Attention Module (CBAM)

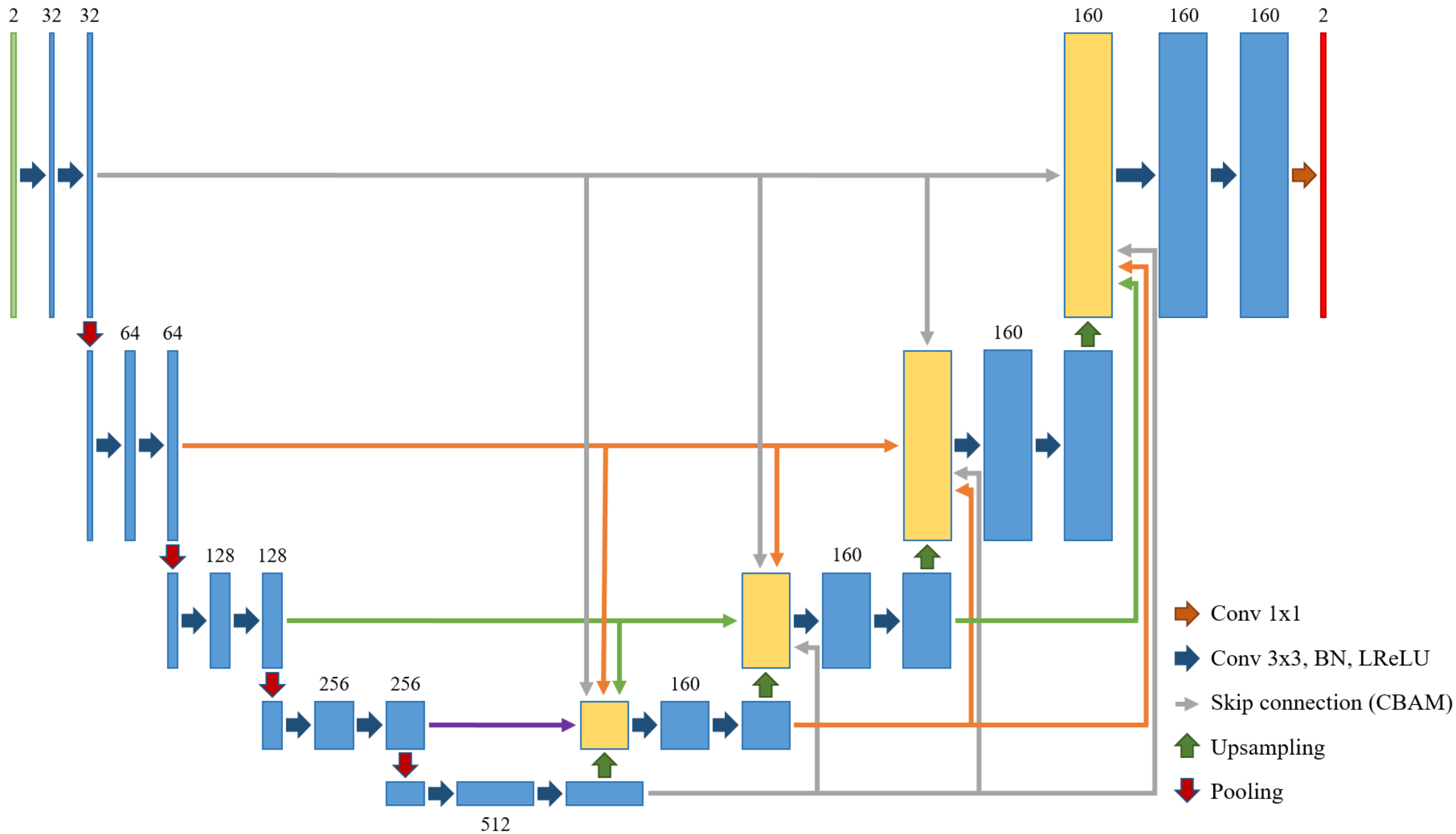


Segmentation model + Attention module



(c) UNet 3+
(Full-scale skip connections)

- U-Net 3+ CBAM



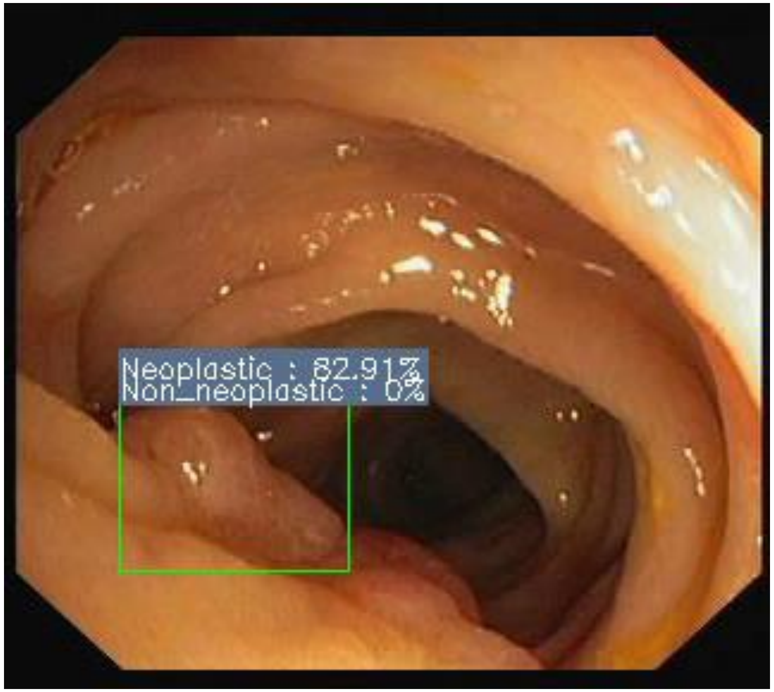
Segmentation results

- Training data: BraTS2019, Testing data: Taichung Veteran Hospital (use T1ce and Flair only).
- WT: whole tumor;   TC: tumor core

Models	**Dice(WT)**	**Dice(TC)**
U-Net	0.849	0.807
U-Net 3+	0.862	0.822
U-Net 3+ (CBAM)	**0.866**	**0.829**
U-Net 3+ (2-Decoder)	0.861	0.807

Short conclusions

- Two AI were designed and trained for colonoscopy exam and organ outlining in CT images.

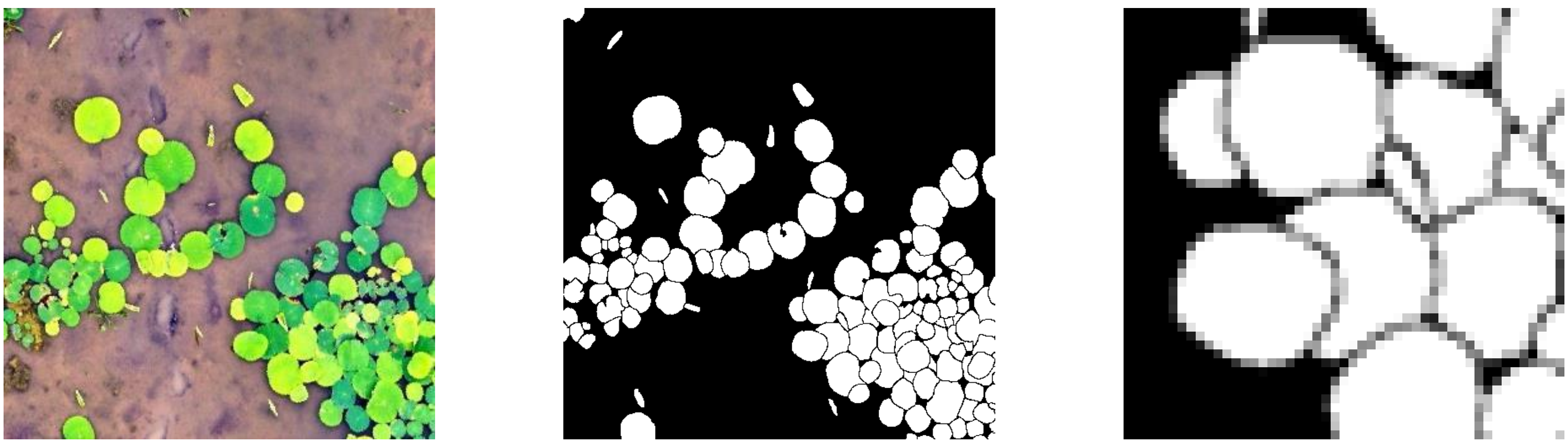


Our value:

- Colonoscopy
  - Expensive GPU server is NOT necessary.
  - Real-time detection and risk assessment
- Organ contouring in CT images
  - Read and Write in DICOM-RT format, compatible with medical image standard.
  - Extend to other organs: kidney, stomach, heart, esophagus, …
  - For the radiologists: An hour of manual work → 10 mins of refining.

Experience

- Labeling groundtruth is time consuming
  - outsourcing (ex. Flow. Inc)
  - Pay attention to the saving image format
  - Does the newbie have sufficient image processing background?



- Perform ablation study when putting different modules together

Thank you for your attention