PRESIMAL Workshop at
Solstrand, 2022

Digital Imaging and Communications in Medicine

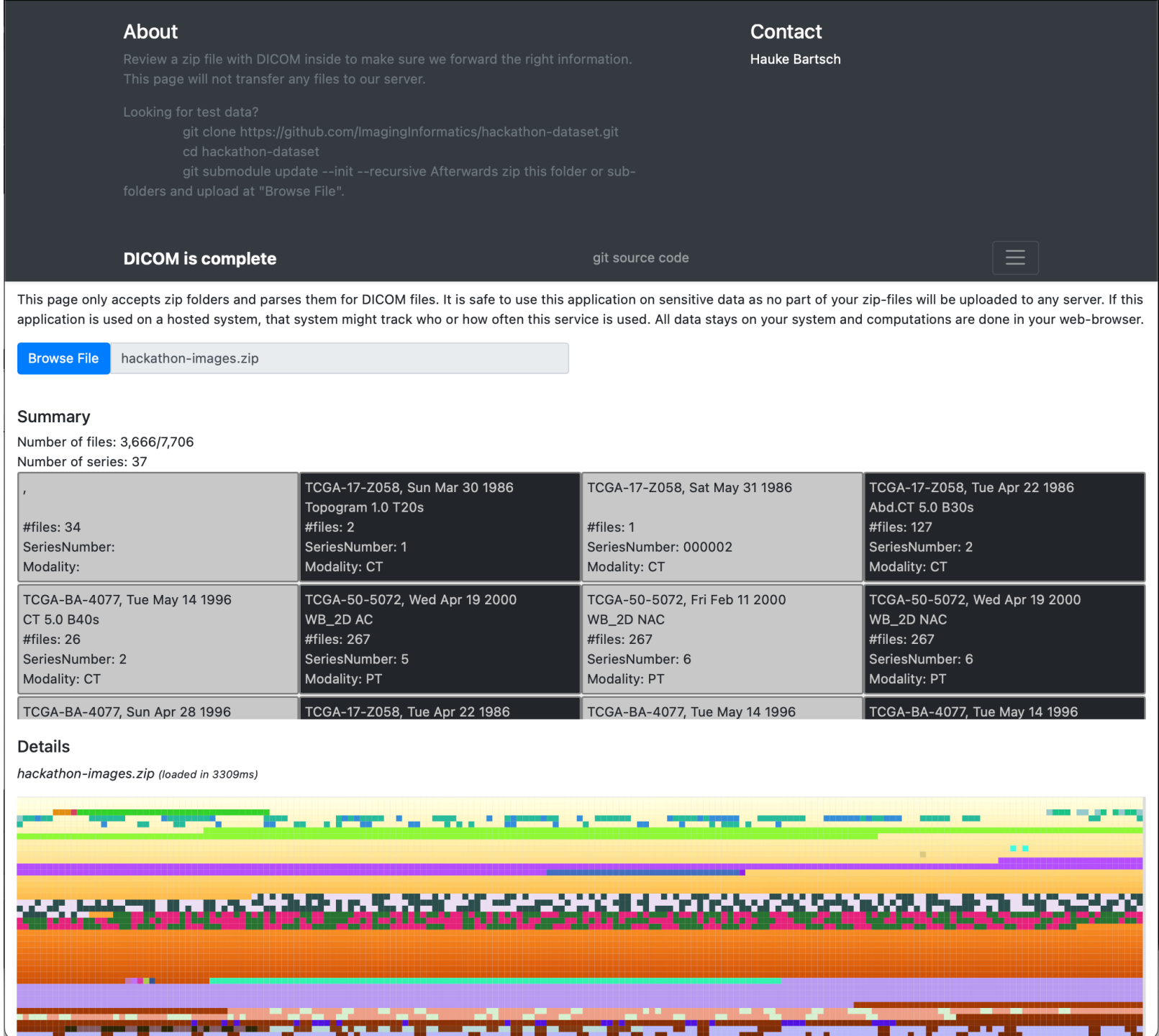
DICOM – there can be only one

“DICOM ensures that all computer systems in clinics, medical imaging centers, and hospitals will work together and distribute the digital medical images correctly, across countries, modalities, and clinics.”

Experiment

https://haukebartsch.github.io/dicom-meta-data-viewer/

SCAN ME



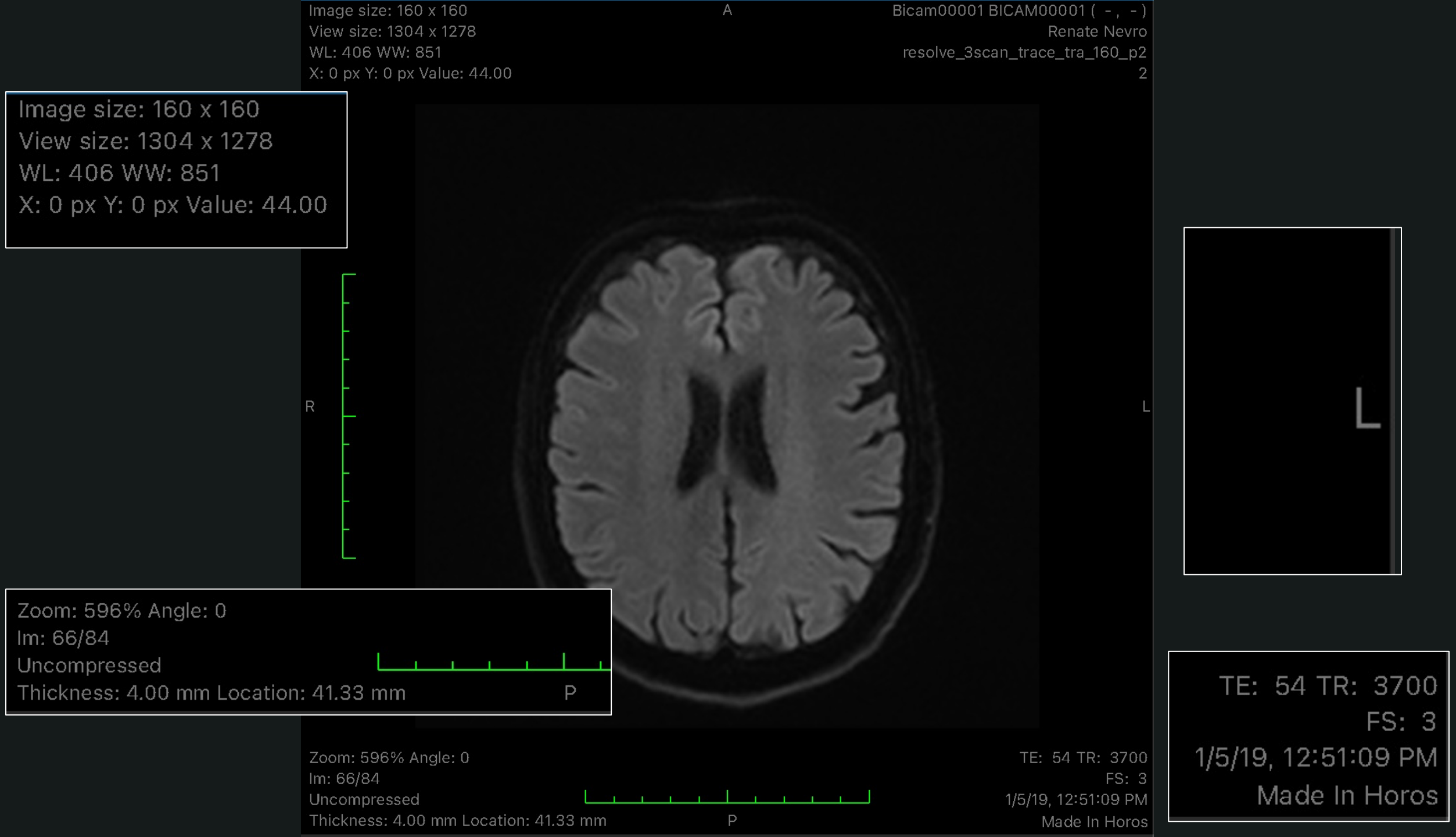
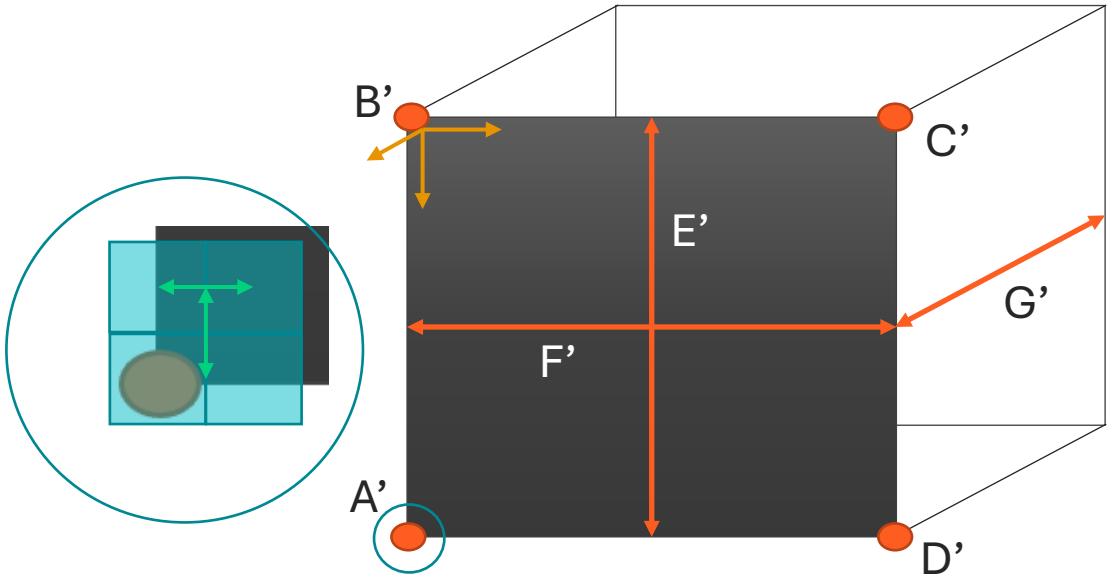


Image size: 160 x 160
View size: 1304 x 1278
WL: 406 WW: 851
X: 0 px Y: 0 px Value: 44.00
A
Bicam00001 BICAM00001 (- , -)
Renate Nevro
resolve_3scan_trace_tra_160_p2
2
Image size: 160 x 160
View size: 1304 x 1278
WL: 406 WW: 851
X: 0 px Y: 0 px Value: 44.00
R
L
L
Zoom: 596% Angle: 0
Im: 66/84
Uncompressed
Thickness: 4.00 mm Location: 41.33 mm
P
TE: 54 TR: 3700
FS: 3
1/5/19, 12:51:09 PM
Made In Horos
Zoom: 596% Angle: 0
Im: 66/84
Uncompressed
Thickness: 4.00 mm Location: 41.33 mm
P
TE: 54 TR: 3700
FS: 3
1/5/19, 12:51:09 PM
Made In Horos

How do we describe things in space?



We need conventions on how to store data for 2D and 3D:
bounding-box + matrix size + encoding per value + number of values per pixel

Tricky corner cases!

What about rotations?

What could possibly go wrong?

Interfile

.hdr .img

Error prone

```
#define MDC_INTF_MAXKEYCHARS 256
char keystr[MDC_INTF_MAXKEYCHARS];
/* the data type */
#define MDC_INTF_STATIC 1
#define MDC_INTF_DYNAMIC 2
#define MDC_INTF_GATED 3
#define MDC_INTF_TOMOGRAPH 4
#define MDC_INTF_CURVE 5
#define MDC_INTF_ROI 6
/* the process status */
#define MDC_INTF_ACQUIRED 1
#define MDC_INTF_RECONSTRUCTED 2
/* gated spect nesting outer level */
#define MDC_INTF_NESTING_SPECT 1
#define MDC_INTF_NESTING_GATED 2
typedef struct MdcInterFile_t {
  int data_type, process_status, pixel_type, gspect_nesting;
  Uint32 width, height, images_per_dimension, time_slots;
  Uint32 data_offset, data_blocks, imagesize, number_images;
  Uint32 energy_windows, frame_groups, time_windows, detector_heads;
  float pixel_xsize, pixel_ysize, slice_thickness, centre_centre_separation;
  float study_duration, image_duration, image_pause, group_pause, ext_rot;
  Int8 patient_rot, patient_orient, slice_orient;
  double version;
} MDC_INTERFILE;
```

Difficult to add new things

```
 short qform_code ;   /*!< NIFTI_XFORM_* code.    */  /*-- all ANALYZE 7.5 ---*/
 short sform_code ;   /*!< NIFTI_XFORM_* code.    */  /*   fields below here  */
                                                     /*   are replaced       */
 float quatern_b ;    /*!< Quaternion b param.    */
 float quatern_c ;    /*!< Quaternion c param.    */
 float quatern_d ;    /*!< Quaternion d param.    */
 float qoffset_x ;    /*!< Quaternion x shift.    */
 float qoffset_y ;    /*!< Quaternion y shift.    */
 float qoffset_z ;    /*!< Quaternion z shift.    */

 float srow_x[4] ;    /*!< 1st row affine transform.   */
 float srow_y[4] ;    /*!< 2nd row affine transform.   */
 float srow_z[4] ;    /*!< 3rd row affine transform.   */

 char intent_name[16];/*!< 'name' or meaning of data.  */

 char magic[4] ;      /*!< MUST be "ni1\0" or "n+1\0". */

} ;                   /**** 348 bytes total ****/
```

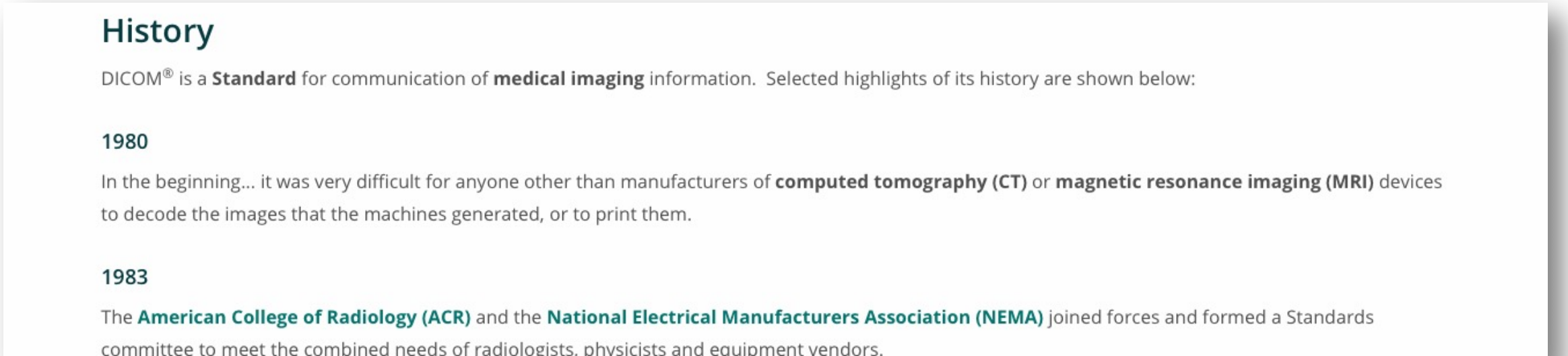
NIFTI header (Mayo/SPM Analyze format + orientation information)

https://en.wikipedia.org/wiki/Analyze_(imaging_software)

DICOM® is a **Standard** for communication of **medical imaging** information.

History of DICOM 1980 -

https://www.dicomstandard.org/history



History

DICOM® is a **Standard** for communication of **medical imaging** information. Selected highlights of its history are shown below:

1980

In the beginning... it was very difficult for anyone other than manufacturers of **computed tomography (CT)** or **magnetic resonance imaging (MRI)** devices to decode the images that the machines generated, or to print them.

1983

The **American College of Radiology (ACR)** and the **National Electrical Manufacturers Association (NEMA)** joined forces and formed a Standards committee to meet the combined needs of radiologists, physicists and equipment vendors.

How is position described in DICOM?

1 Patient Level:	2 Study Level:	3 Series Level:
Patient's Name	Study Instance UID	Series Instance UID
Patient ID	Study Date	Series Number
Patient's Sex	Study Time	Manufacturer
Patient's Birth Date	Referring Physician's Name	
Specific Character Set	Study ID	
	Accession Number	

Attributes

(group) *(tag)*

(0018,0051) - Patient Position relative to the imaging equipment space : “FFS” – Feet first - Supine *(Face up)*

(0020,0032) – Image Position (Patient): "-142.7265625\-302.7265625\-270.5"

(0020,0037) – Image Orientation (Patient): "1\0\0\0\1\0”

(0020,1041) – Slice Location: "270.5”

(rows) *(columns)*

(0028,0030) – Pixel Spacing: “0.703125, 0.703125”

Even more details:

https://dicom.innolitics.com/ciods/ct-image/general-series

Create a DICOM file

DICOM — -zsh — 106×47

```
[hauke@Haukes-MacBook-Pro-4 DICOM % ls -laghtr
total 0
drwxr-xr-x  2 wheel    64B Sep 14 07:26 .
drwxr-xr-x  5 wheel   160B Sep 14 07:26 ..
[hauke@Haukes-MacBook-Pro-4 DICOM % touch empty.dump
[hauke@Haukes-MacBook-Pro-4 DICOM % dump2dcm empty.dump one.dcm
W: output transfer syntax unknown, assuming --write-xfer-little
[hauke@Haukes-MacBook-Pro-4 DICOM % dcmftest one.dcm
yes: one.dcm
[hauke@Haukes-MacBook-Pro-4 DICOM % dcmdump one.dcm

# Dicom-File-Format

# Dicom-Meta-Information-Header
# Used TransferSyntax: Little Endian Explicit
(0002,0000) UL 194                                      #   4, 1 FileMetaInfo
(0002,0001) OB 00\01                                    #   2, 1 FileMetaInfo
(0002,0002) UI [1.2.276.0.7230010.3.1.0.1]              #  26, 1 MediaStorage
(0002,0003) UI [1.2.276.0.7230010.3.1.4.0.74507.1663133221.580797] #  50, 1 M
(0002,0010) UI =LittleEndianExplicit                    #  20, 1 TransferSynt
(0002,0012) UI [1.2.276.0.7230010.3.0.3.6.6]            #  28, 1 Implementati
(0002,0013) SH [OFFIS_DCMTK_366]                        #  16, 1 Implementati

# Dicom-Data-Set
# Used TransferSyntax: Little Endian Explicit
[hauke@Haukes-MacBook-Pro-4 DICOM % dcmdump one.dcm > step1.dump
[hauke@Haukes-MacBook-Pro-4 DICOM % vim step1.dump
[hauke@Haukes-MacBook-Pro-4 DICOM % dump2dcm step1.dump two.dcm
[hauke@Haukes-MacBook-Pro-4 DICOM % dcmdump two.dcm

# Dicom-File-Format

# Dicom-Meta-Information-Header
# Used TransferSyntax: Little Endian Explicit
(0002,0000) UL 194                                      #   4, 1 FileMetaInformationGroupLength
(0002,0001) OB 00\01                                    #   2, 1 FileMetaInformationVersion
(0002,0002) UI [1.2.276.0.7230010.3.1.0.1]              #  26, 1 MediaStorageSOPClassUID
(0002,0003) UI [1.2.276.0.7230010.3.1.4.0.74507.1663133221.580797] #  50, 1 MediaStorageSOPInstanceUID
(0002,0010) UI =LittleEndianExplicit                    #  20, 1 TransferSyntaxUID
(0002,0012) UI [1.2.276.0.7230010.3.0.3.6.6]            #  28, 1 ImplementationClassUID
(0002,0013) SH [OFFIS_DCMTK_366]                        #  16, 1 ImplementationVersionName

# Dicom-Data-Set
# Used TransferSyntax: Little Endian Explicit
(0010,0010) PN [WORKSHOP01]                             #  10, 1 PatientName
(0010,0020) LO [WORKSHOP01]                             #  10, 1 PatientID
hauke@Haukes-MacBook-Pro-4 DICOM %
```

DICOM — vim step1.dump — 107×66

```
1
2  # Dicom-File-Format
3
4  # Dicom-Meta-Information-Header
5  # Used TransferSyntax: Little Endian Explicit
6  (0002,0000) UL 194                                      #   4, 1 FileMetaInformationGroupLength
7  (0002,0001) OB 00\01                                    #   2, 1 FileMetaInformationVersion
8  (0002,0002) UI [1.2.276.0.7230010.3.1.0.1]              #  26, 1 MediaStorageSOPClassUID
9  (0002,0003) UI [1.2.276.0.7230010.3.1.4.0.74507.1663133221.580797] #  50, 1 MediaStorageSOPInstanceUID
10 (0002,0010) UI =LittleEndianExplicit                    #  20, 1 TransferSyntaxUID
11 (0002,0012) UI [1.2.276.0.7230010.3.0.3.6.6]            #  28, 1 ImplementationClassUID
12 (0002,0013) SH [OFFIS_DCMTK_366]                        #  16, 1 ImplementationVersionName
13
14 # Dicom-Data-Set
15 # Used TransferSyntax: Little Endian Explicit
16 (0010,0010) PN [WORKSHOP01]
17 (0010,0020) LN [WORKSHOP01]
18 (0020,000D) UI [1.3.6.1.4.1.45037.5.2.1.123456789]
19 (0020,000E) UI [1.3.6.1.4.1.45037.5.2.1.987655444]
20
~
```

Magic numbers

1.3.6.1.4.1.45037.5.2.1.6279.6001.314138616411061948052843767346

Organization root: 1.3.6.1.4.1.45037 (whodunit)

Descriptive suffix: 5.2.1

Unique suffix: 6279.6001.314138616411061948052843767346

Get an organization id if you generate DICOM files:

http://www.oid-info.com/get/1.3.6.1.4.1.45037

SOPInstanceUID, SeriesInstanceUID, StudyInstanceUID, Frame of Reference UID

```
[hauke@Haukes-MacBook-Pro-4 DICOM % img2dcm --series-from two.dcm image.jpg three.dcm
[hauke@Haukes-MacBook-Pro-4 DICOM % dcmdump three.dcm

# Dicom-File-Format

# Dicom-Meta-Information-Header
# Used TransferSyntax: Little Endian Explicit
(0002,0000) UL 196                                      #   4, 1 FileMetaInformationGroupLength
(0002,0001) OB 00\01                                    #   2, 1 FileMetaInformationVersion
(0002,0002) UI =SecondaryCaptureImageStorage            #  26, 1 MediaStorageSOPClassUID
(0002,0003) UI [1.2.276.0.7230010.3.1.4.0.15096.1663134574.193501] #  50, 1 MediaStorageSOPInstanceUID
(0002,0010) UI =JPEGFullProgression:Non-hierarchical:Process10+12 #  22, 1 TransferSyntaxUID
(0002,0012) UI [1.2.276.0.7230010.3.0.3.6.6]            #  28, 1 ImplementationClassUID
(0002,0013) SH [OFFIS_DCMTK_366]                        #  16, 1 ImplementationVersionName

# Dicom-Data-Set
# Used TransferSyntax: JPEG Full Progression, Non-hierarchical, Process 10+12
(0008,0005) CS [ISO_IR 100]                             #  10, 1 SpecificCharacterSet
(0008,0016) UI =SecondaryCaptureImageStorage            #  26, 1 SOPClassUID
(0008,0018) UI [1.2.276.0.7230010.3.1.4.0.15096.1663134574.193501] #  50, 1 SOPInstanceUID
(0008,0020) DA (no value available)                     #   0, 0 StudyDate
(0008,0030) TM (no value available)                     #   0, 0 StudyTime
(0008,0050) SH (no value available)                     #   0, 0 AccessionNumber
(0008,0064) CS [WSD]                                    #   4, 1 ConversionType
(0008,0070) LO (no value available)                     #   0, 0 Manufacturer
(0008,0090) PN (no value available)                     #   0, 0 ReferringPhysicianName
(0010,0010) PN [WORKSHOP01]                             #  10, 1 PatientName
(0010,0020) LO [WORKSHOP01]                             #  10, 1 PatientID
(0010,0030) DA (no value available)                     #   0, 0 PatientBirthDate
(0010,0040) CS (no value available)                     #   0, 0 PatientSex
(0020,000d) UI [1.3.6.1.4.1.45037.5.2.1.123456789]      #  34, 1 StudyInstanceUID
(0020,000e) UI [1.3.6.1.4.1.45037.5.2.1.987655444]      #  34, 1 SeriesInstanceUID
(0020,0010) SH (no value available)                     #   0, 0 StudyID
(0020,0011) IS (no value available)                     #   0, 0 SeriesNumber
(0020,0013) IS (no value available)                     #   0, 0 InstanceNumber
(0020,0020) CS (no value available)                     #   0, 0 PatientOrientation
(0028,0002) US 1                                        #   2, 1 SamplesPerPixel
(0028,0004) CS [MONOCHROME2]                            #  12, 1 PhotometricInterpretation
(0028,0010) US 10                                       #   2, 1 Rows
(0028,0011) US 10                                       #   2, 1 Columns
(0028,0100) US 8                                        #   2, 1 BitsAllocated
(0028,0101) US 8                                        #   2, 1 BitsStored
(0028,0102) US 7                                        #   2, 1 HighBit
(0028,0103) US 0                                        #   2, 1 PixelRepresentation
(0028,2110) CS [01]                                     #   2, 1 LossyImageCompression
(0028,2114) CS [ISO_10918_1]                            #  12, 1 LossyImageCompressionMethod
(7fe0,0010) OB (PixelSequence #=2)                      # u/l, 1 PixelData
  (fffe,e000) pi (no value available)                     #   0, 1 Item
  (fffe,e000) pi ff\d8\ff\db\00\43\00\03\02\02\03\02\02\03\03\03\03\04\03\03\04\05... # 326, 1 Item
(fffe,e0dd) na (SequenceDelimitationItem)               #   0, 0 SequenceDelimitationItem
hauke@Haukes-MacBook-Pro-4 DICOM %
```

Private Tags

(0013,0000): "6”
(0013,0010): "CTP”
(0013,1010): "TCGA-LUAD”
(0013,1013): "77779002"

DICOM is complex because medical imaging has many components, but it is not difficult.

Meaning of DICOM tags:

https://dicom.innolitics.com/ciods/rt-plan/rt-series/00080060

How to build a medical workstation

All tools are freely available, reliable and fast

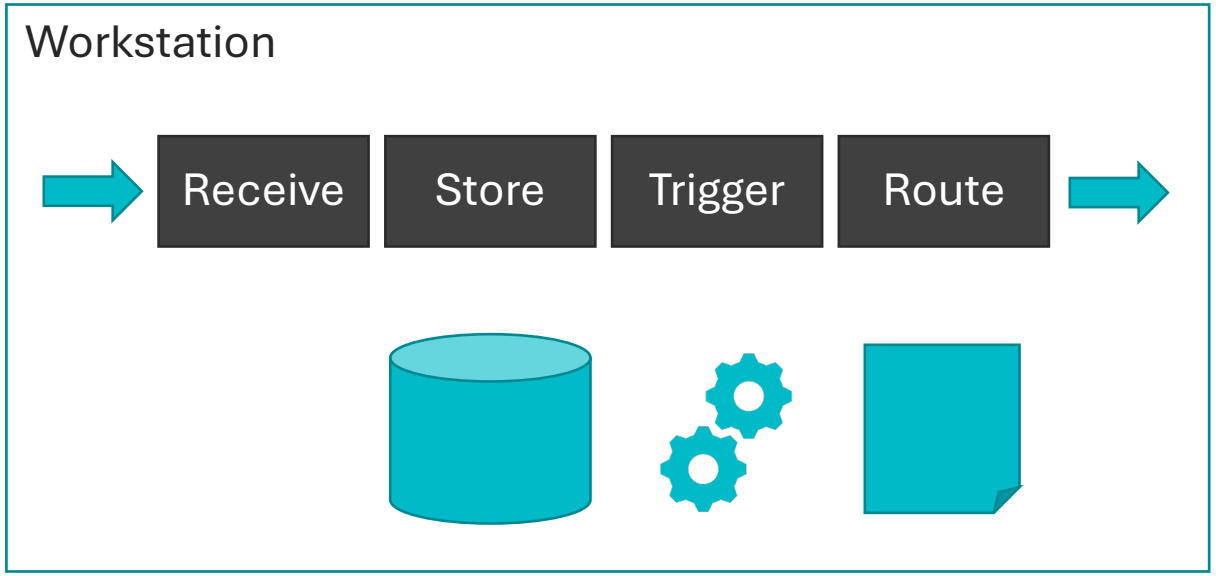
Hospital Systems

PACS

Modality

Modality

PACS



Modality

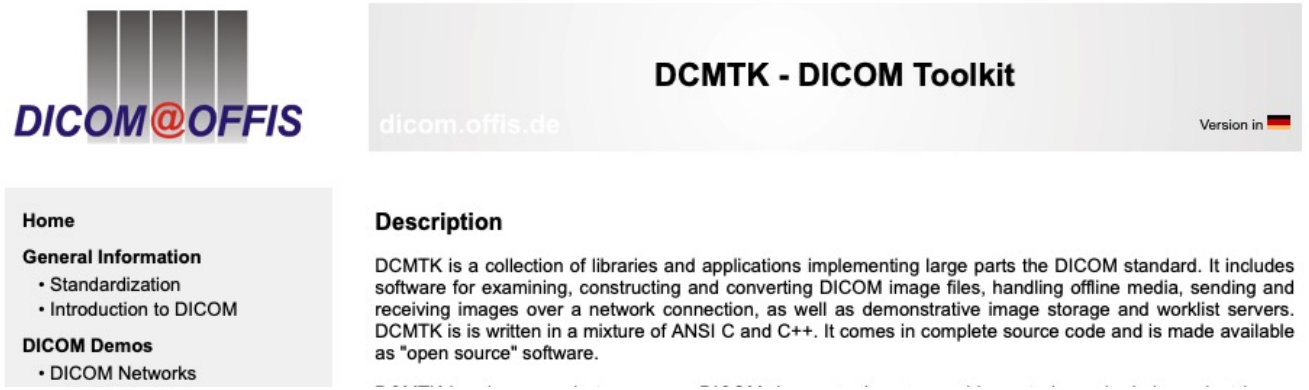
PACS

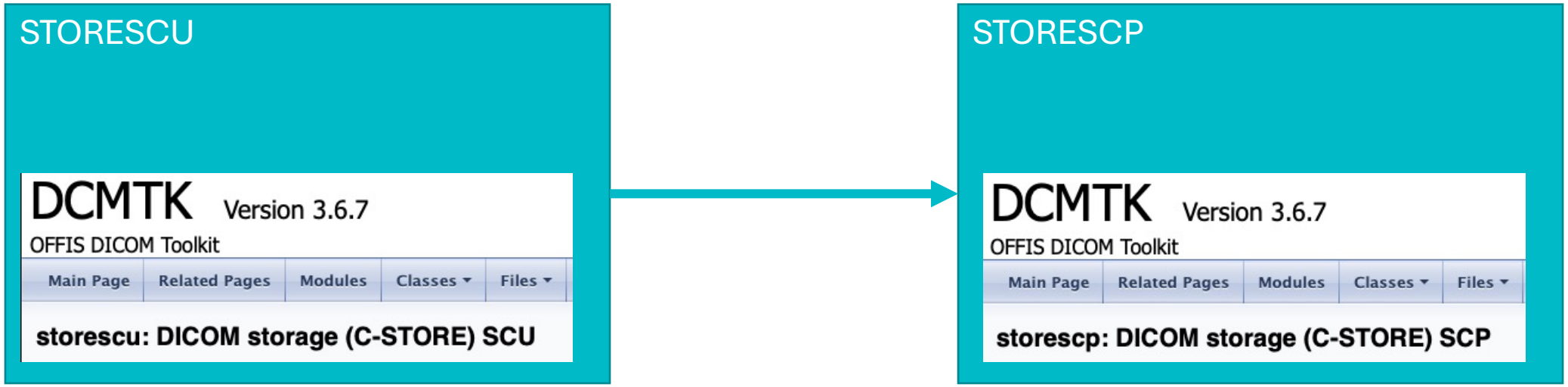
Workstation

Workstation

DCMTK

(C++ solution for Mac, Windows, Linux)



Example:

https://github.com/HaukeBartsch/data-transfer-station