MAIA

# Insight into images

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# Outline

- Insight into images
- Contents
  - Image information
  - Image Modalities
  - Image formats
  - DICOM, PACs

Some slides taken from O. Díaz (UB).

# Before starting …

What is a digital hospital?

# Before starting …

What sort of (**digital**) health data can you think of?

# Introduction

- **Health Record** (non-imaging data)
  - Clinical document with patient information to provide support to healthcare members.
  - Includes all medical information regarding a person.
  - Unique ID number to each patient/client.
  - Confidential.
  - Potential problems:
    - Large pieces of information -> time.
    - Fragmentation.
    - Illegibility.
    - Anonymisation

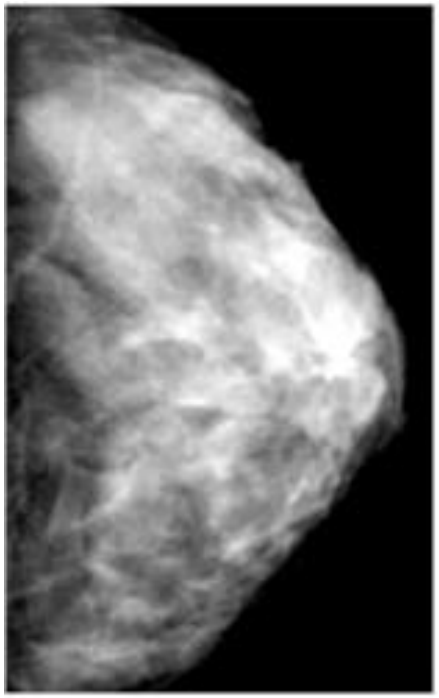
Handwriting

Welcome to the digital data era:
**Electronic Health Record** (EHR)

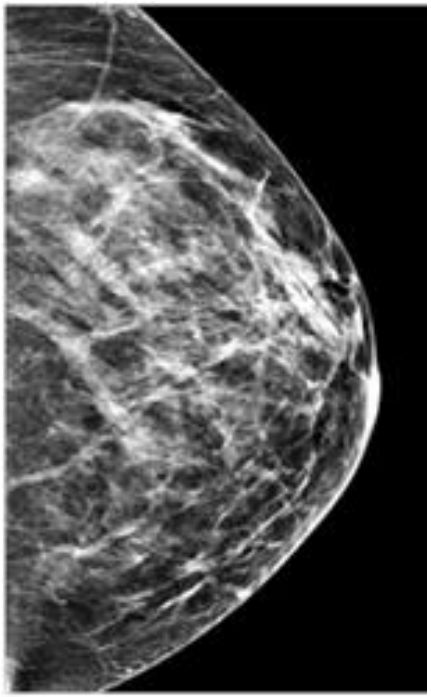
# Introduction

- **Medical image** (imaging data)

Analogic



Digital

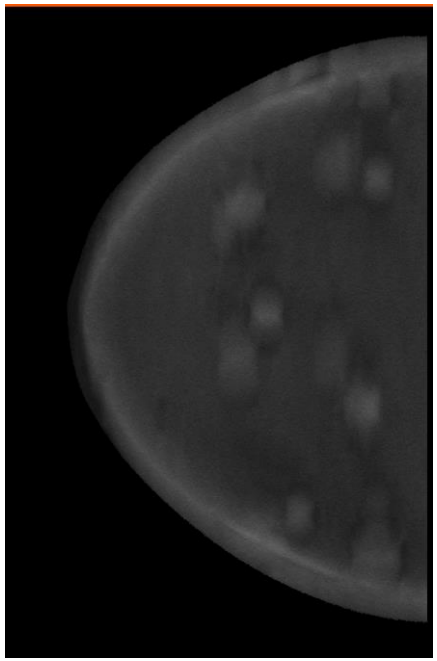


# Introduction

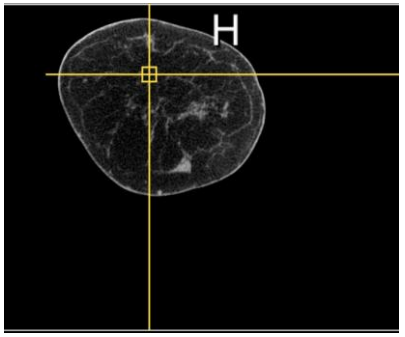
- **Medical image** (imaging data)

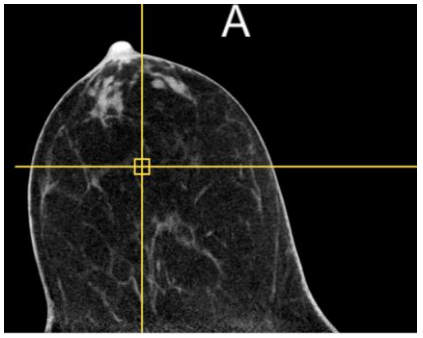
2D

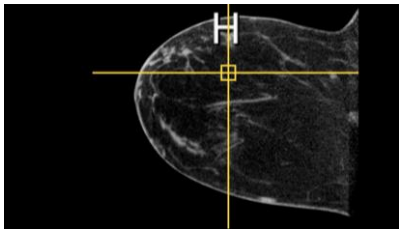
2.2D



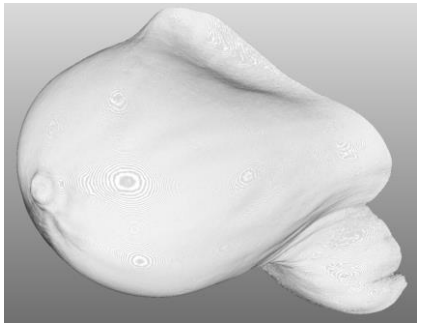
3D



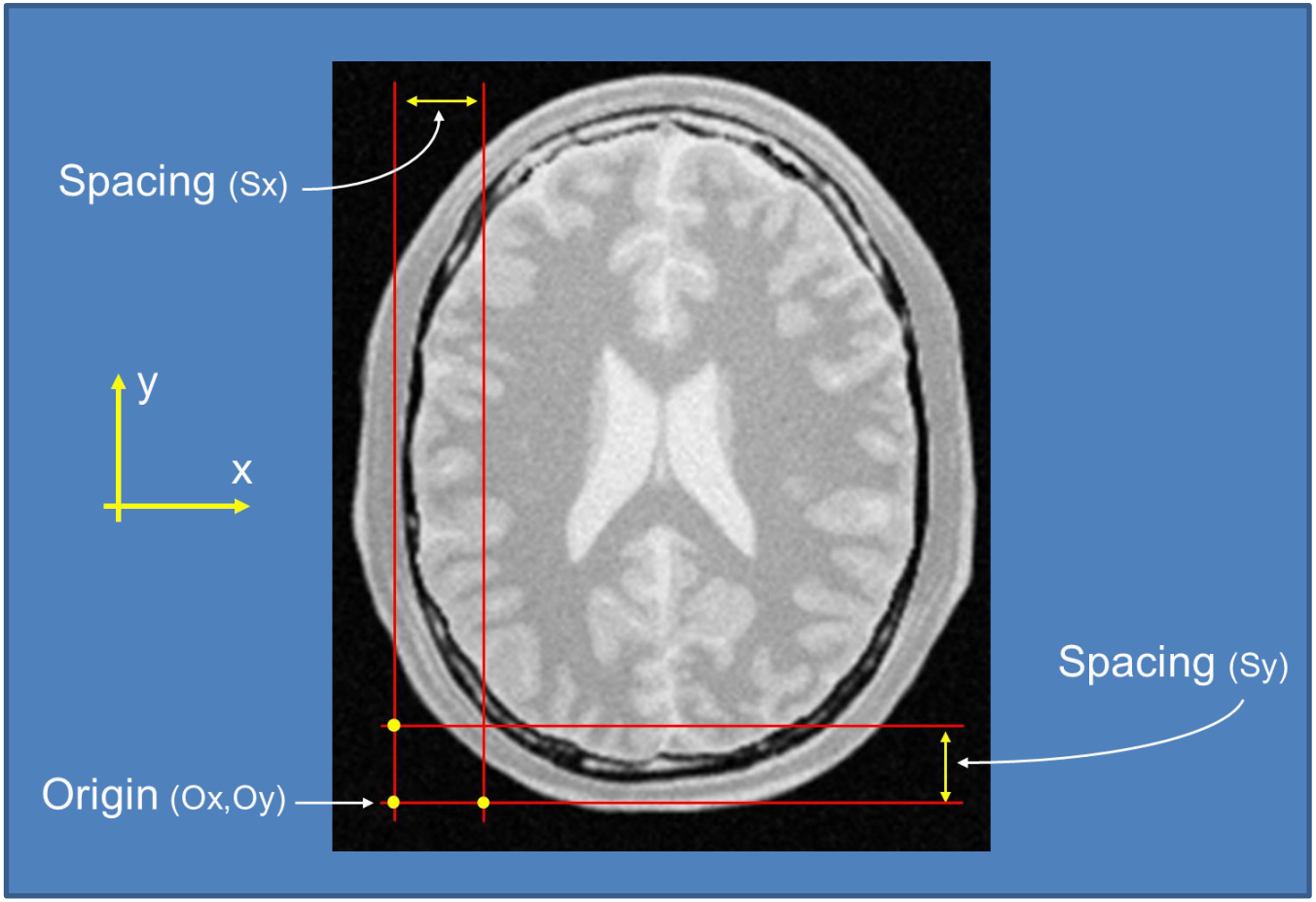

4D



# Image Information

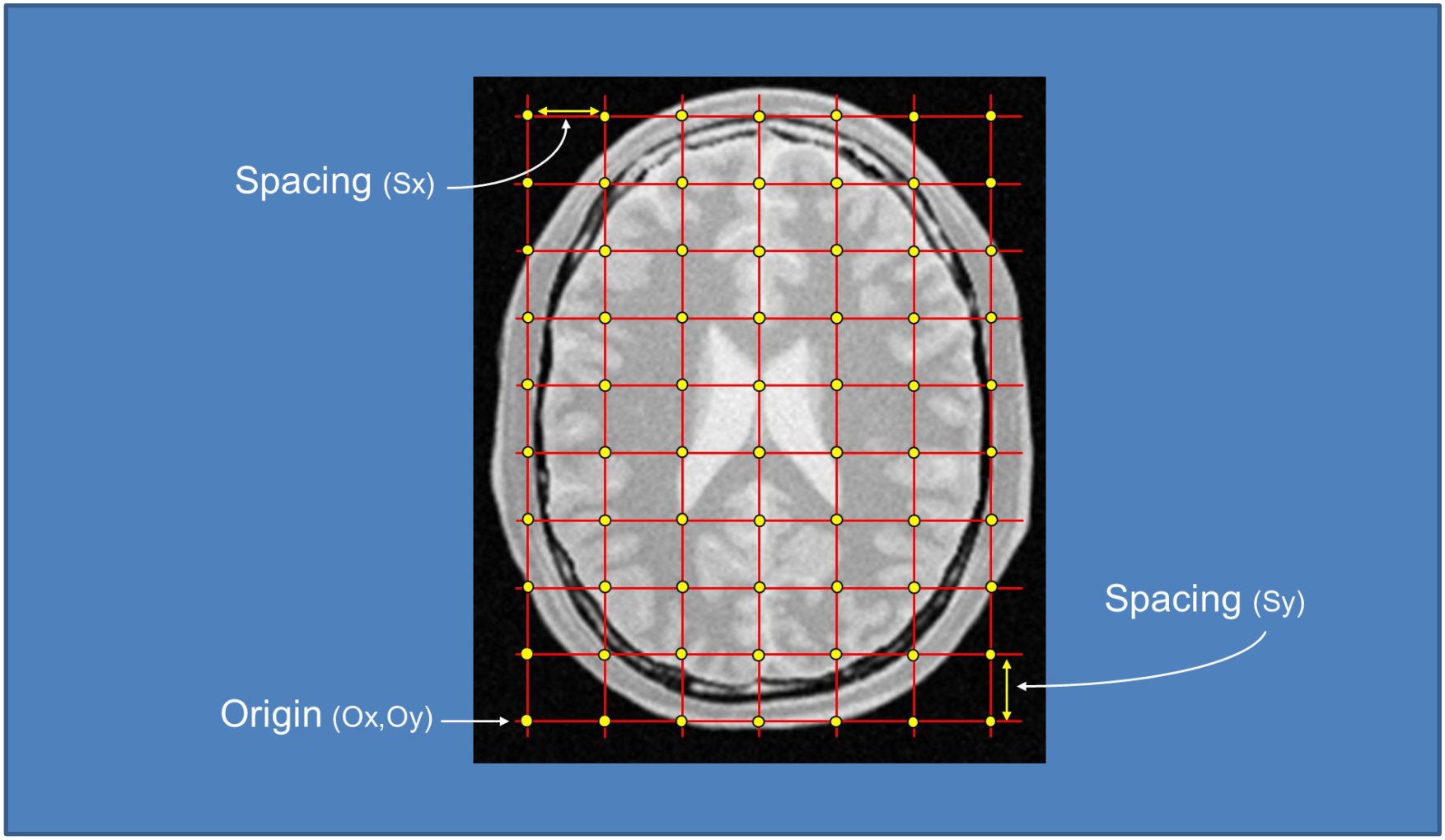
# Pixels and images

- What is an image?
- Discrete grid representation of a continuous signal



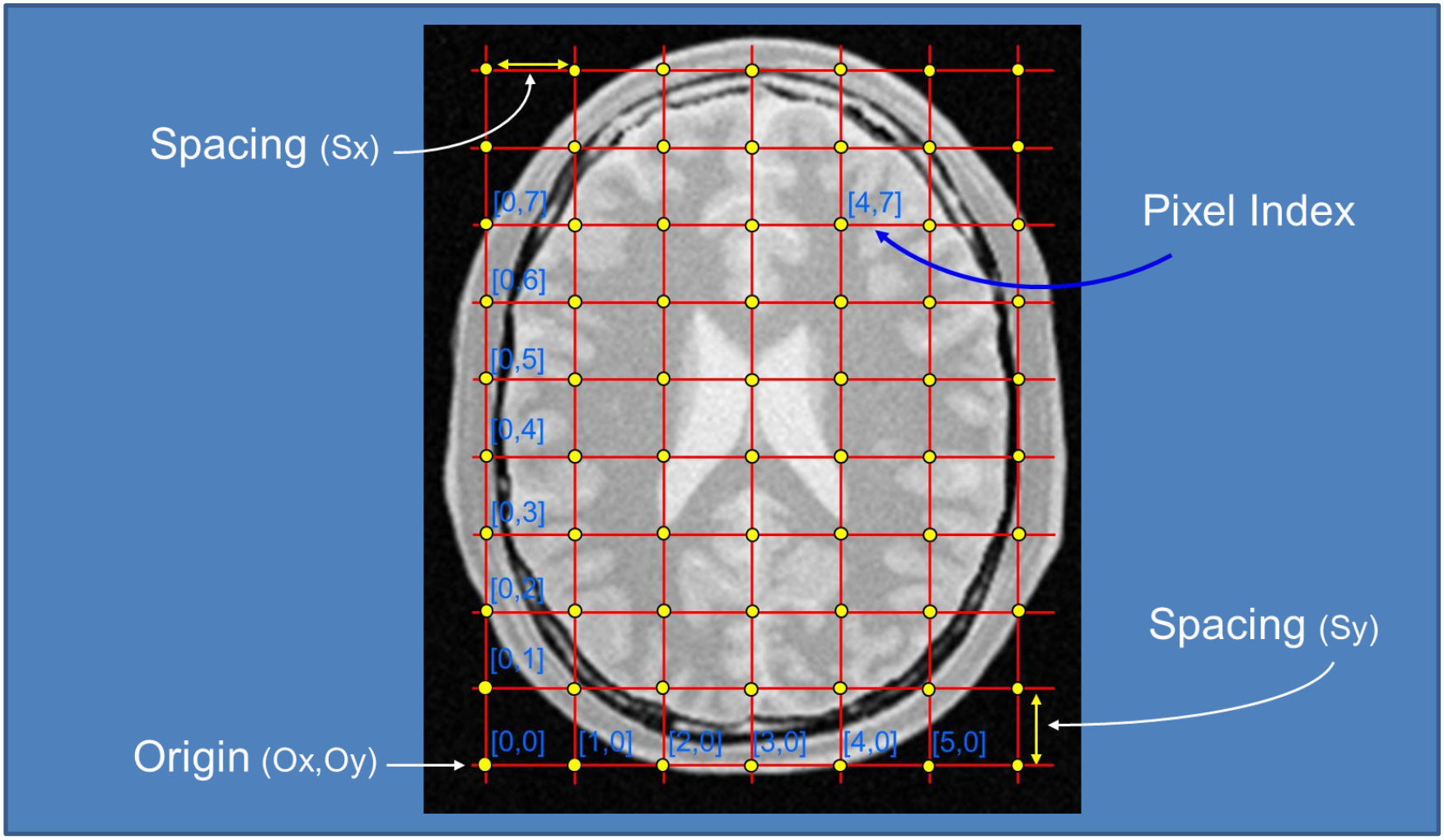
# Pixels and images

- Sampling grid



# Pixels and images

- Image index



# Pixels and images

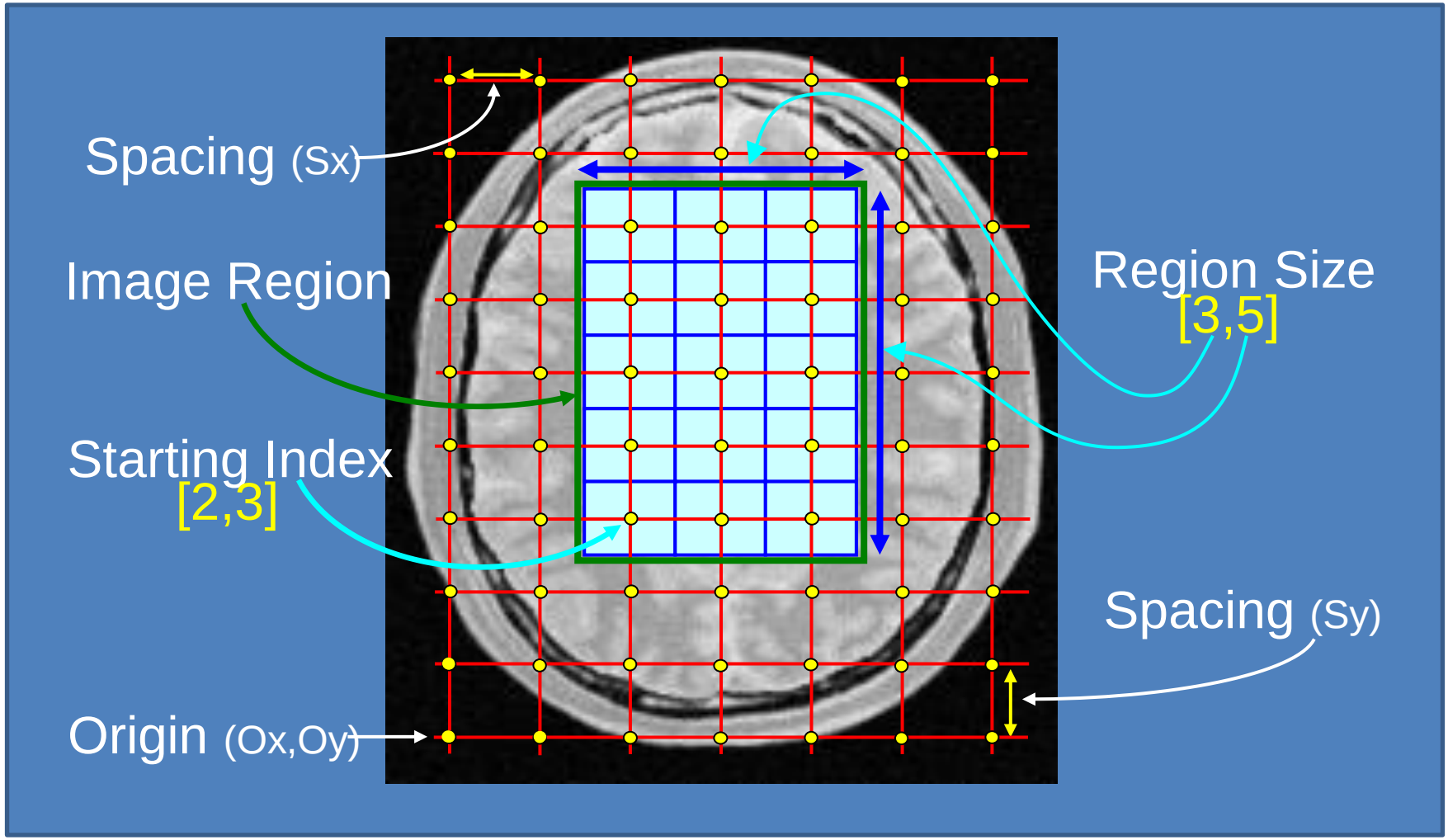
- Pixel and physical coordinates
- Conversion

$$P[0] = Index[0] \times Spacing[0] + Origin[0]$$
$$P[1] = Index[1] \times Spacing[1] + Origin[1]$$

$$Index[0] = floor( ( P[0] - Origin[0] ) / Spacing[0] + 0.5 )$$
$$Index[1] = floor( ( P[1] - Origin[1] ) / Spacing[1] + 0.5 )$$

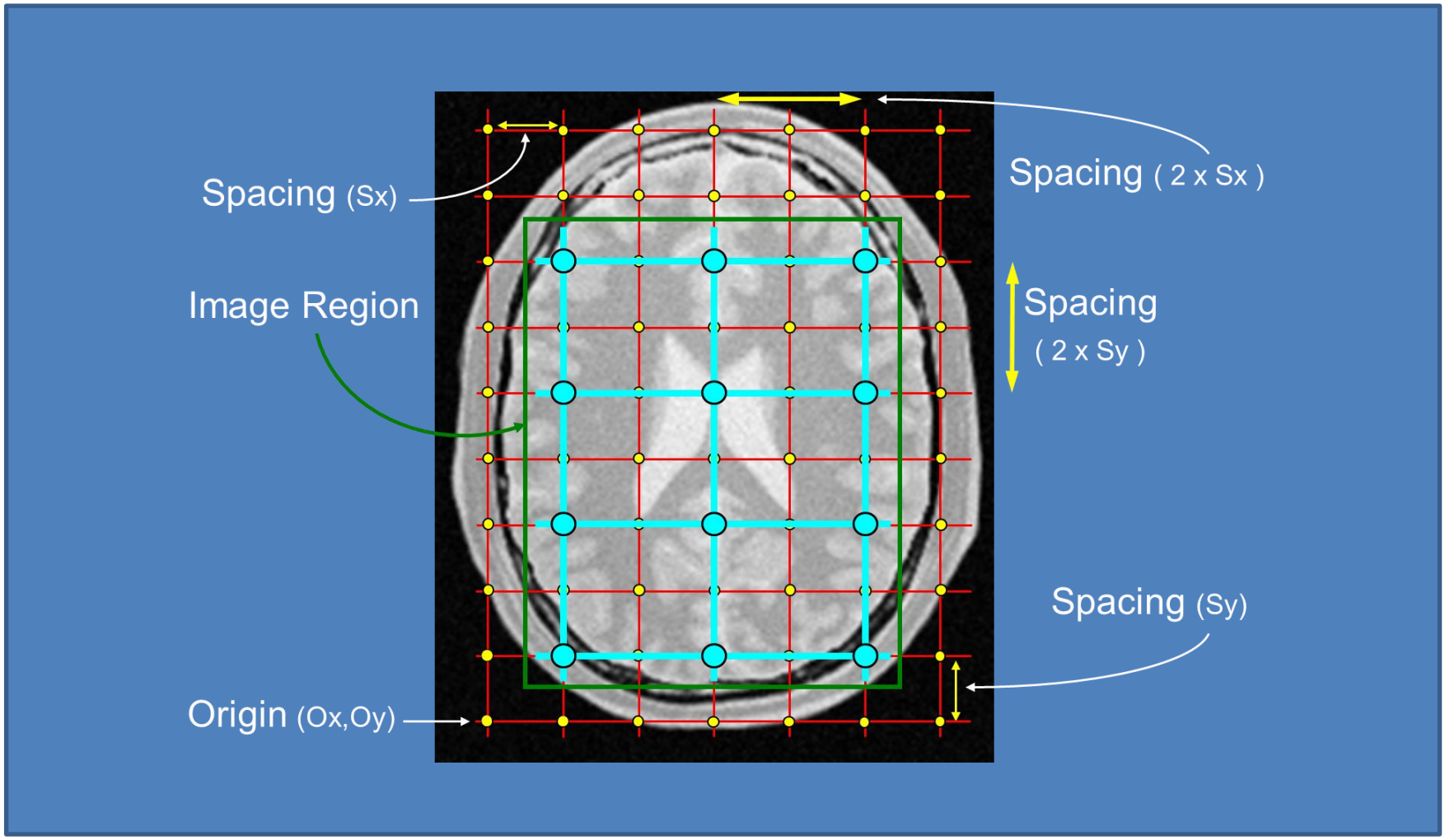
# Pixels and images

- Image Region



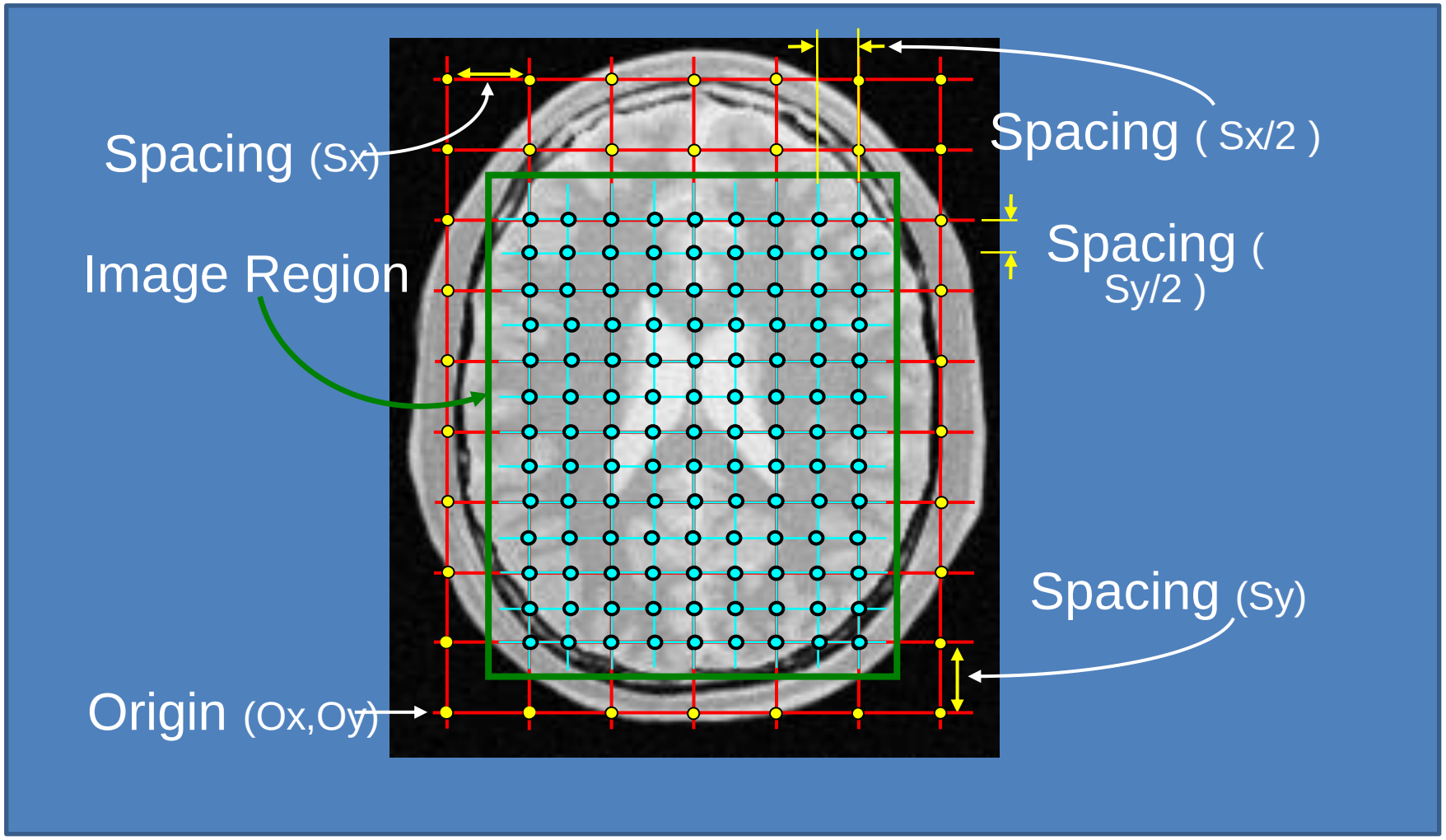
# Pixels and images

- Resampling: sub-sampling



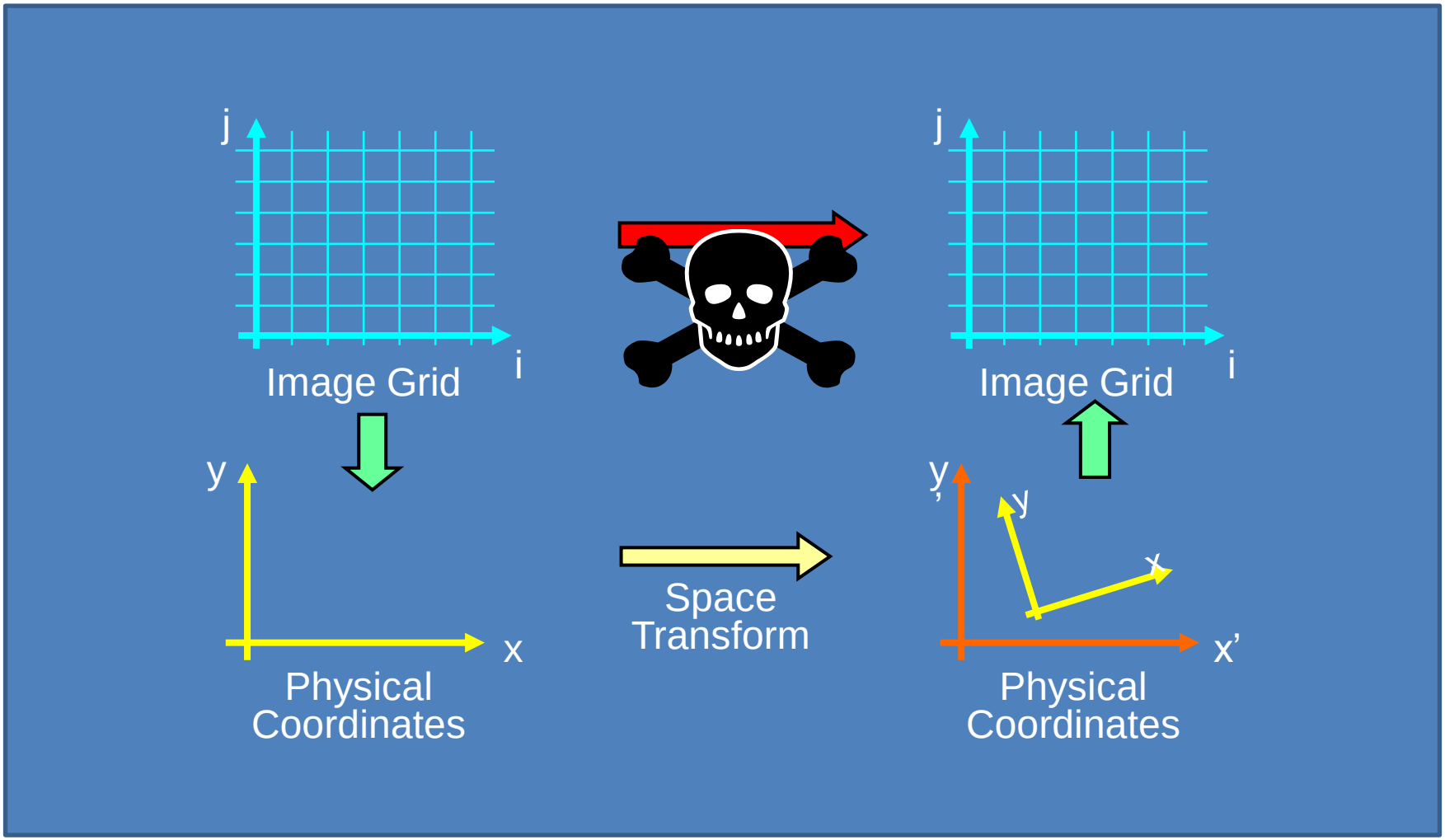
# Pixels and images

- Resampling: super-sampling



# Pixels and images

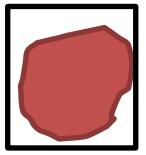
- How do we compare images?



# Pixels and images

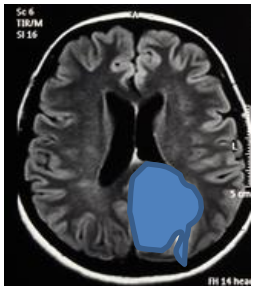
- Comparing images

**Patient A: 600 pixels lesion**

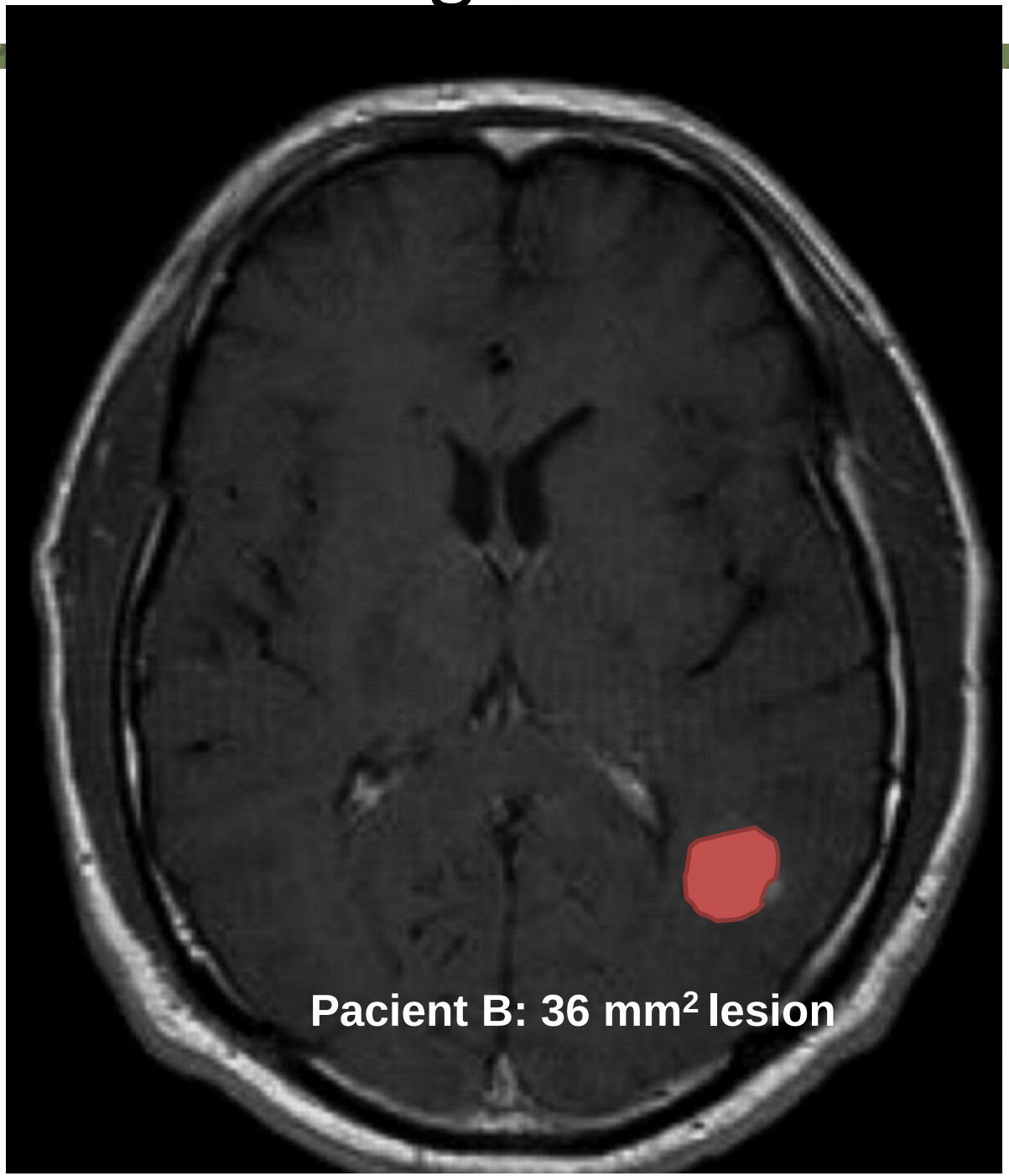


**Pacient B: 800 pixels lesion**

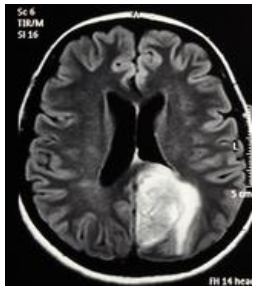
# Pixels and Images



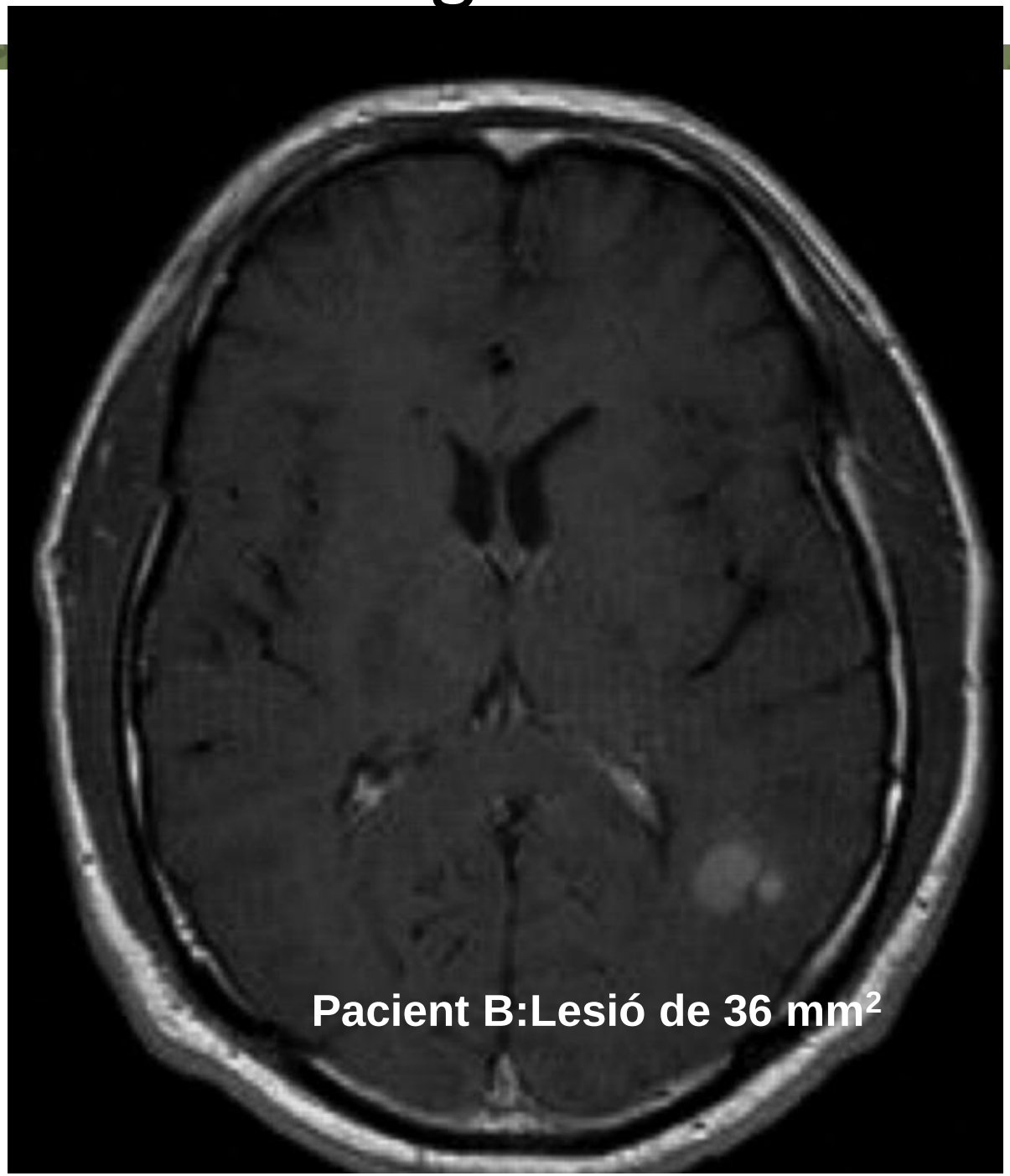
**Pacient A: 300mm$^2$ lesion**



# Pixels and Images



**Pacient A: lesió de300mm$^2$**

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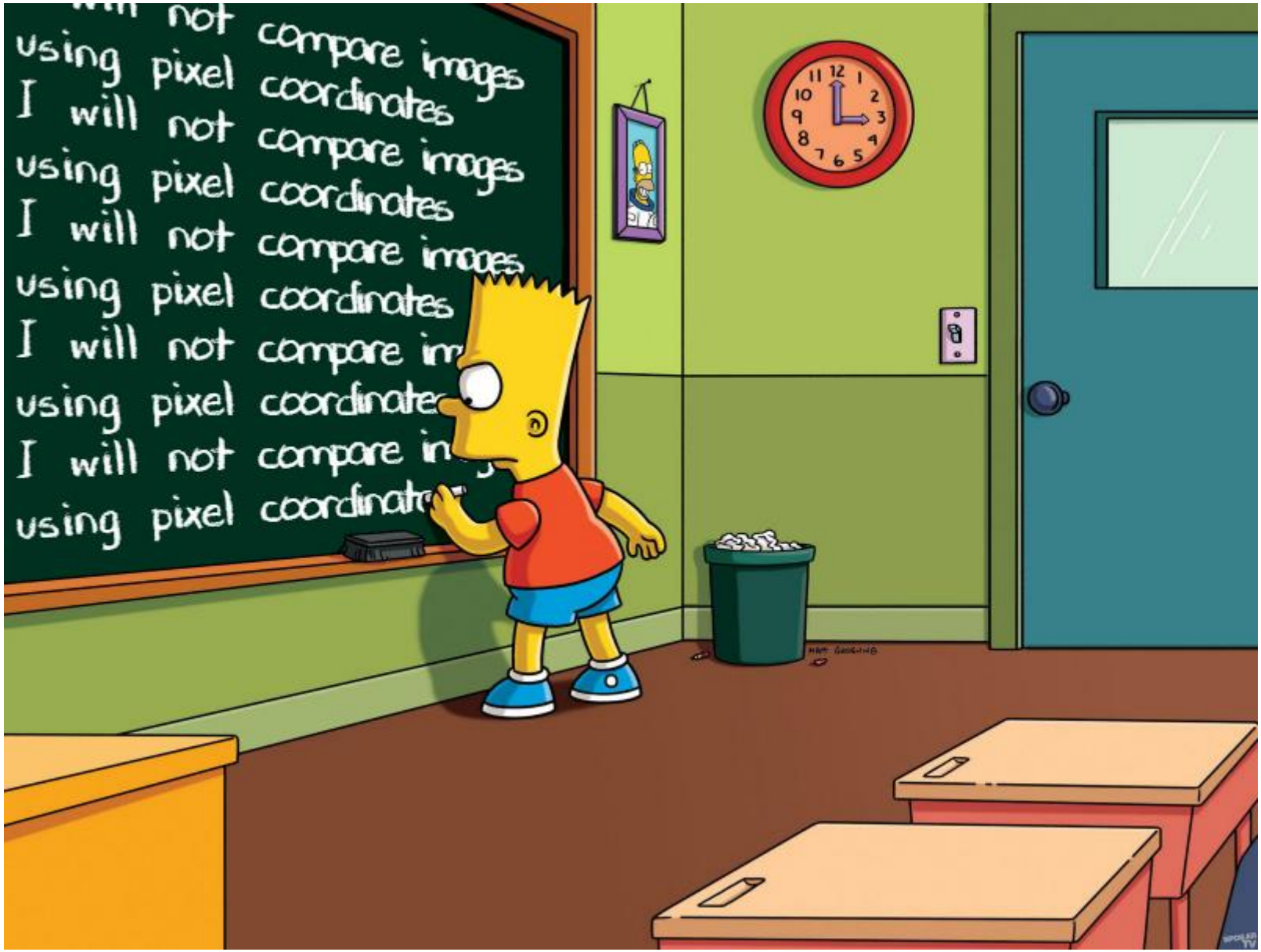
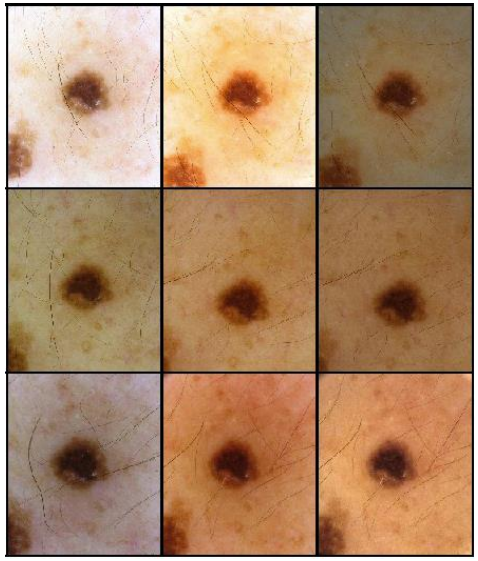
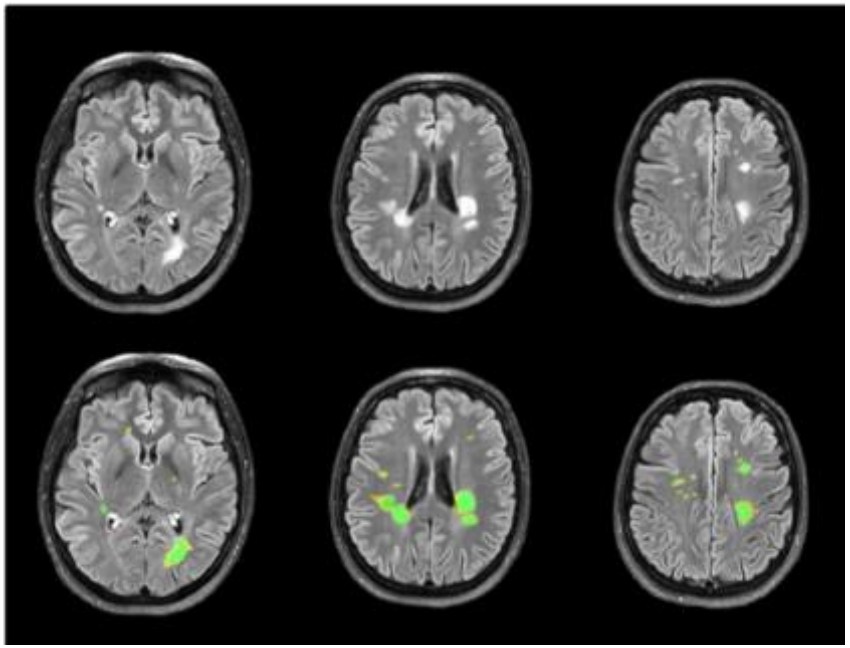
# Pixels and Images

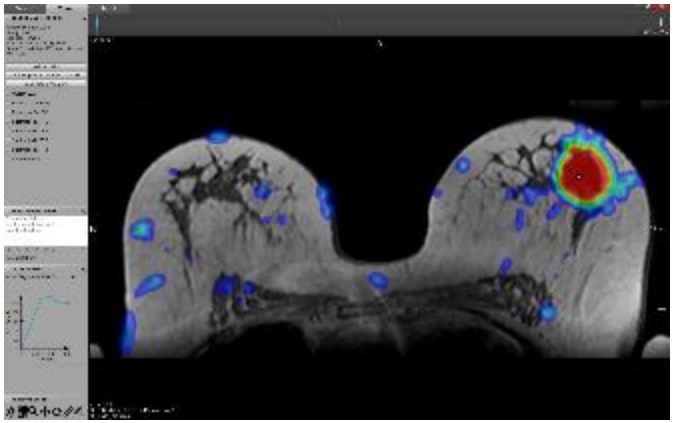


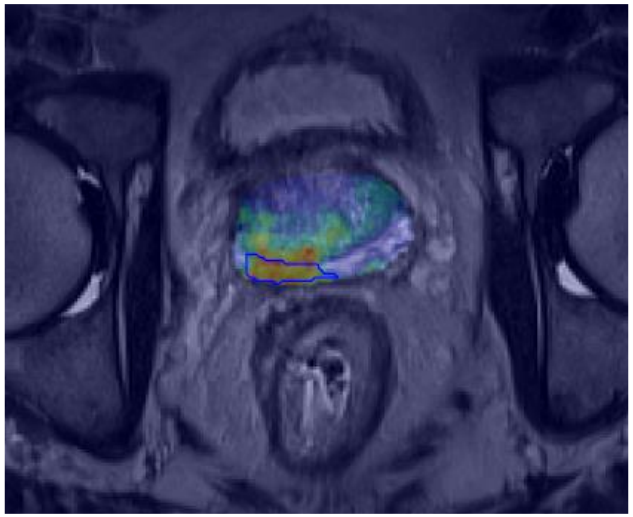
# Image Modalities

# Image Modalities



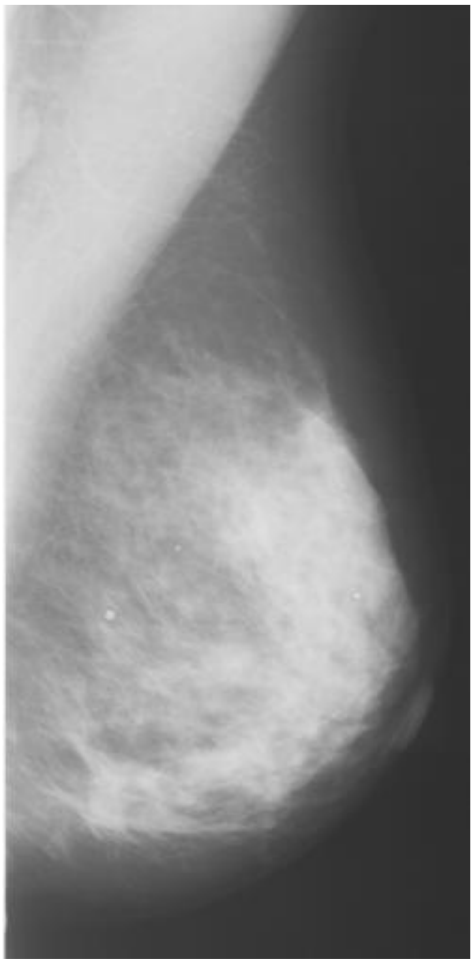


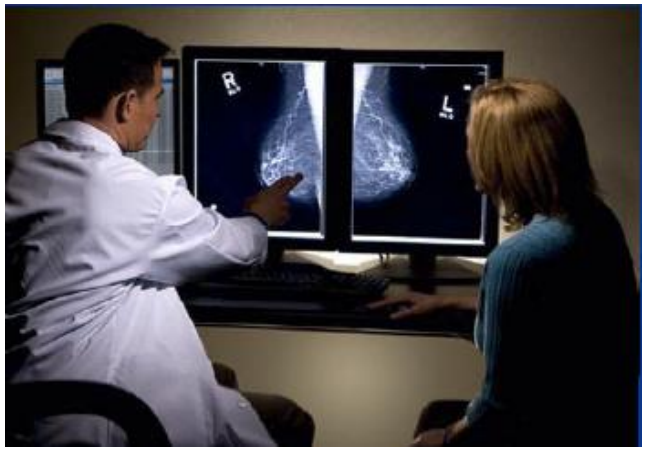


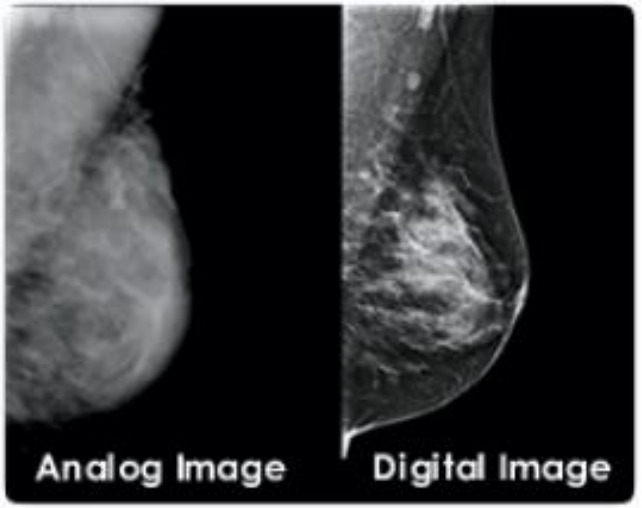


# Breast imaging

- Mammography

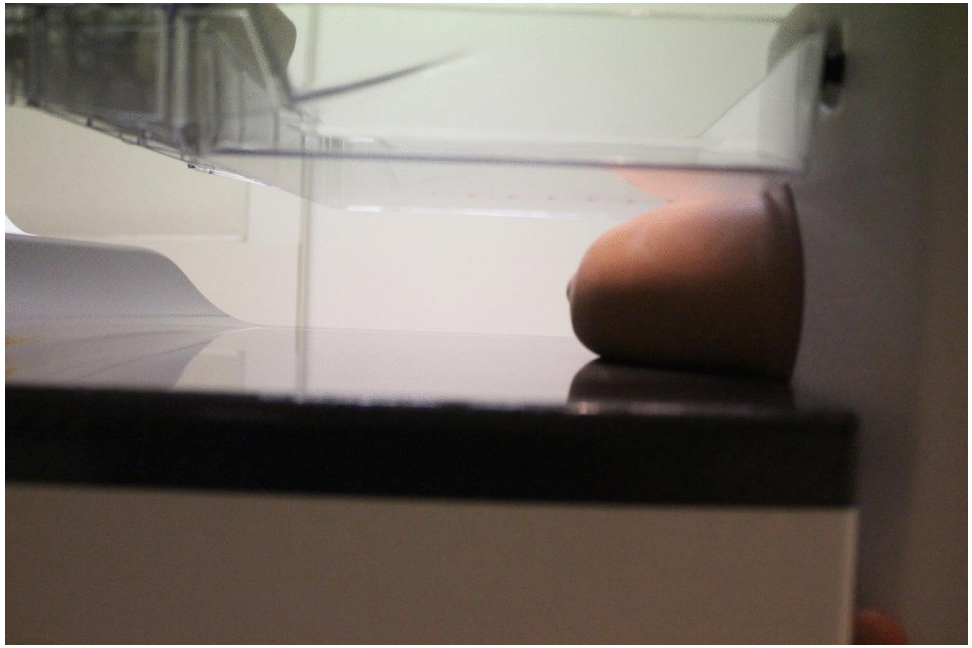






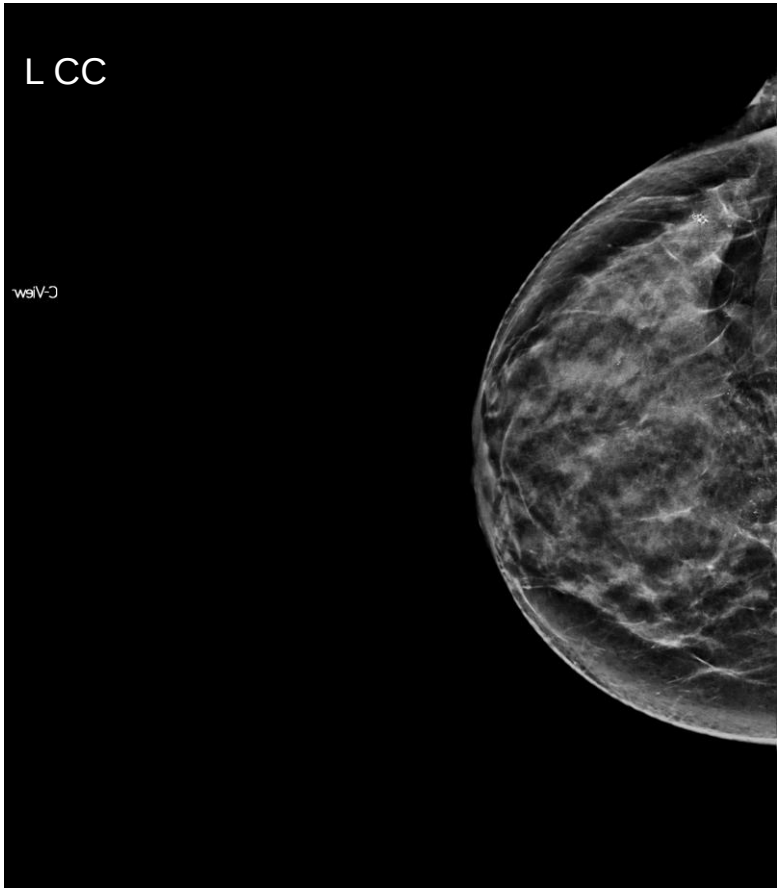
# Breast Imaging

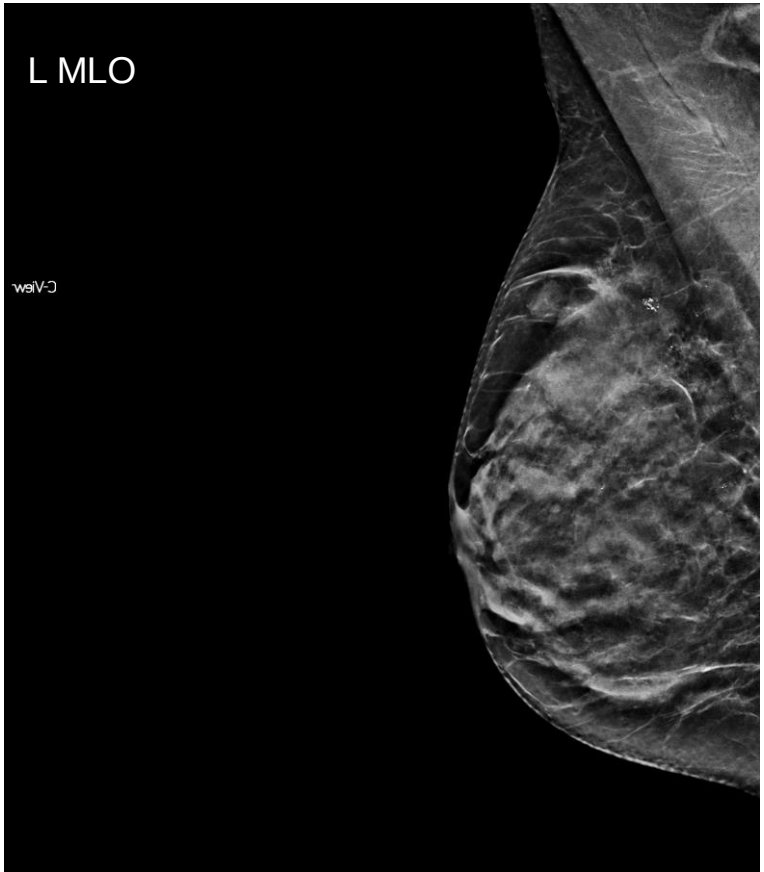
- Compression
  - Minimize patient movement
  - Increase imaging area (minimise tissue overlap)
  - Less noise (reduce breast thickness, less scattering)



# Breast imaging

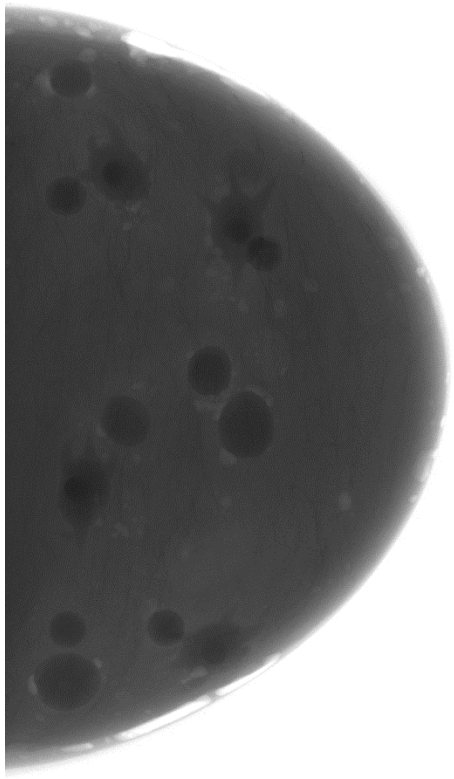
- FFDM
  - 50-100 µm in pixel size
  - 12-16 bits per pixel
  - Image size of 8-50 MB

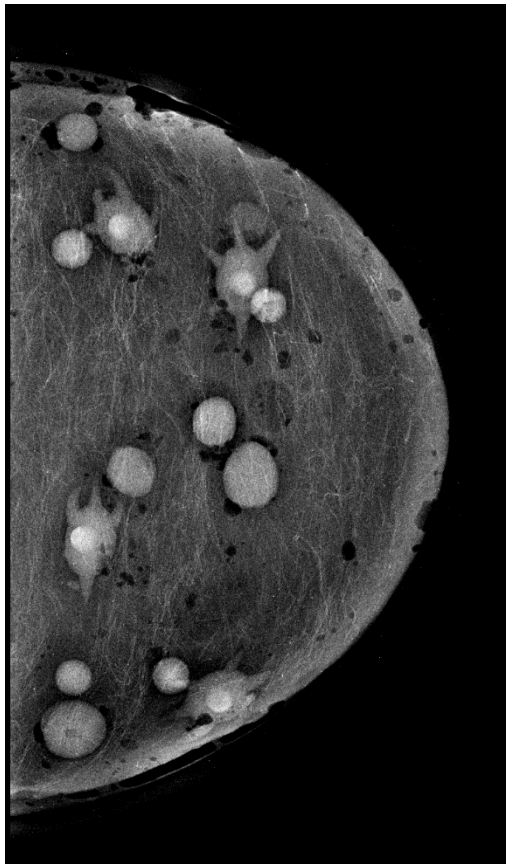


# Breast imaging

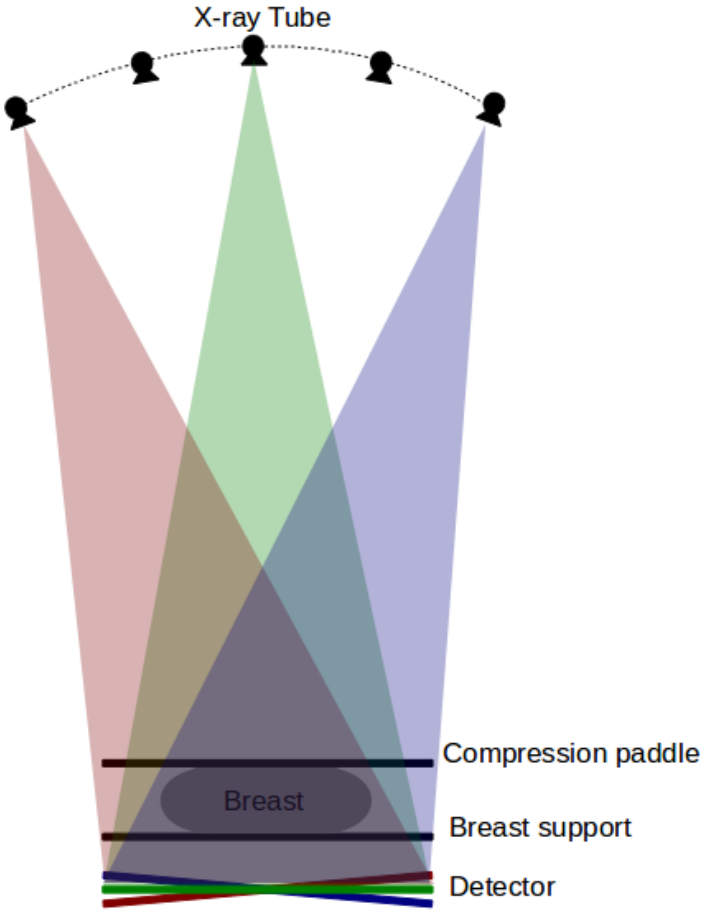
- Phantoms



# Breast imaging

- DBT Tomosynthesis





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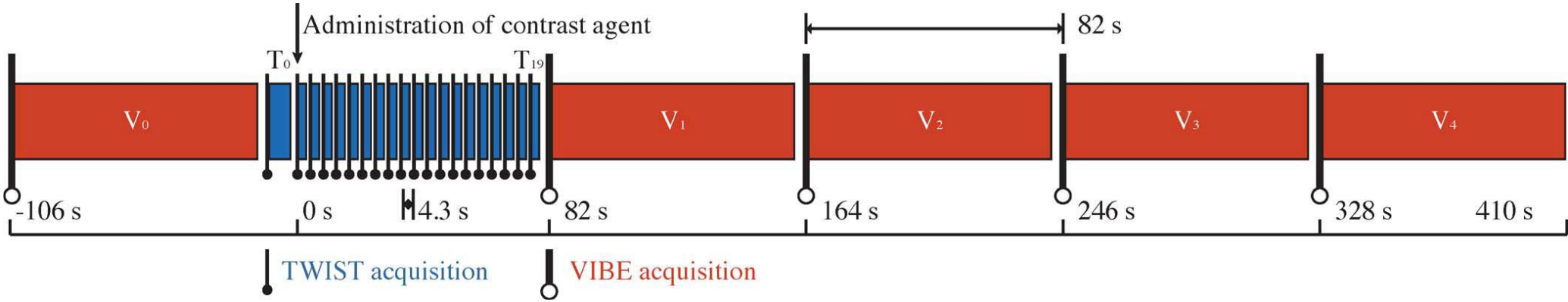
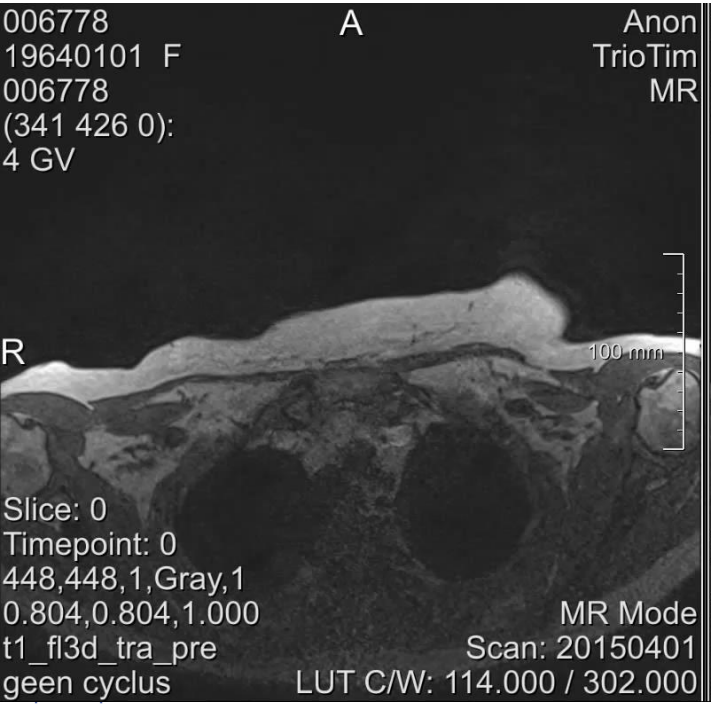
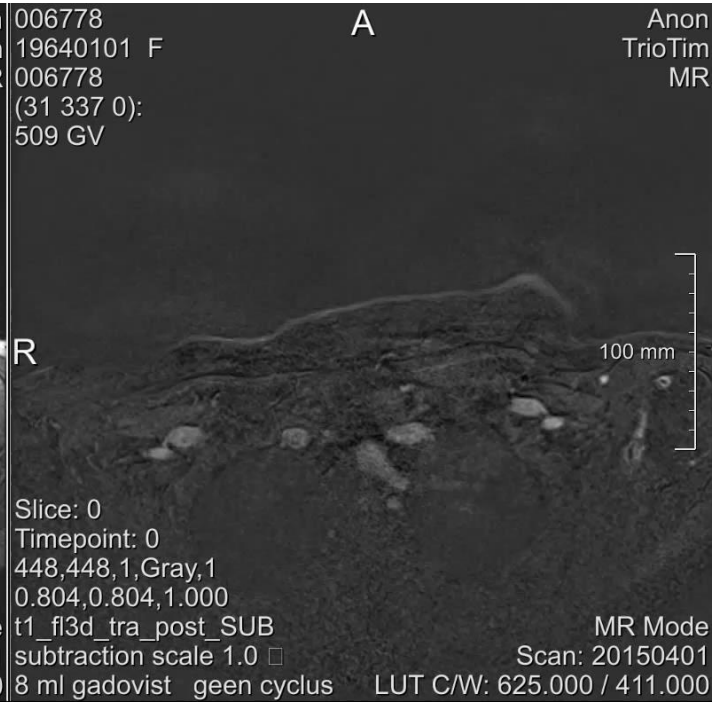
# Breast Imaging

- Dynamic Contrast Enhanced MRI (DCE-MRI)



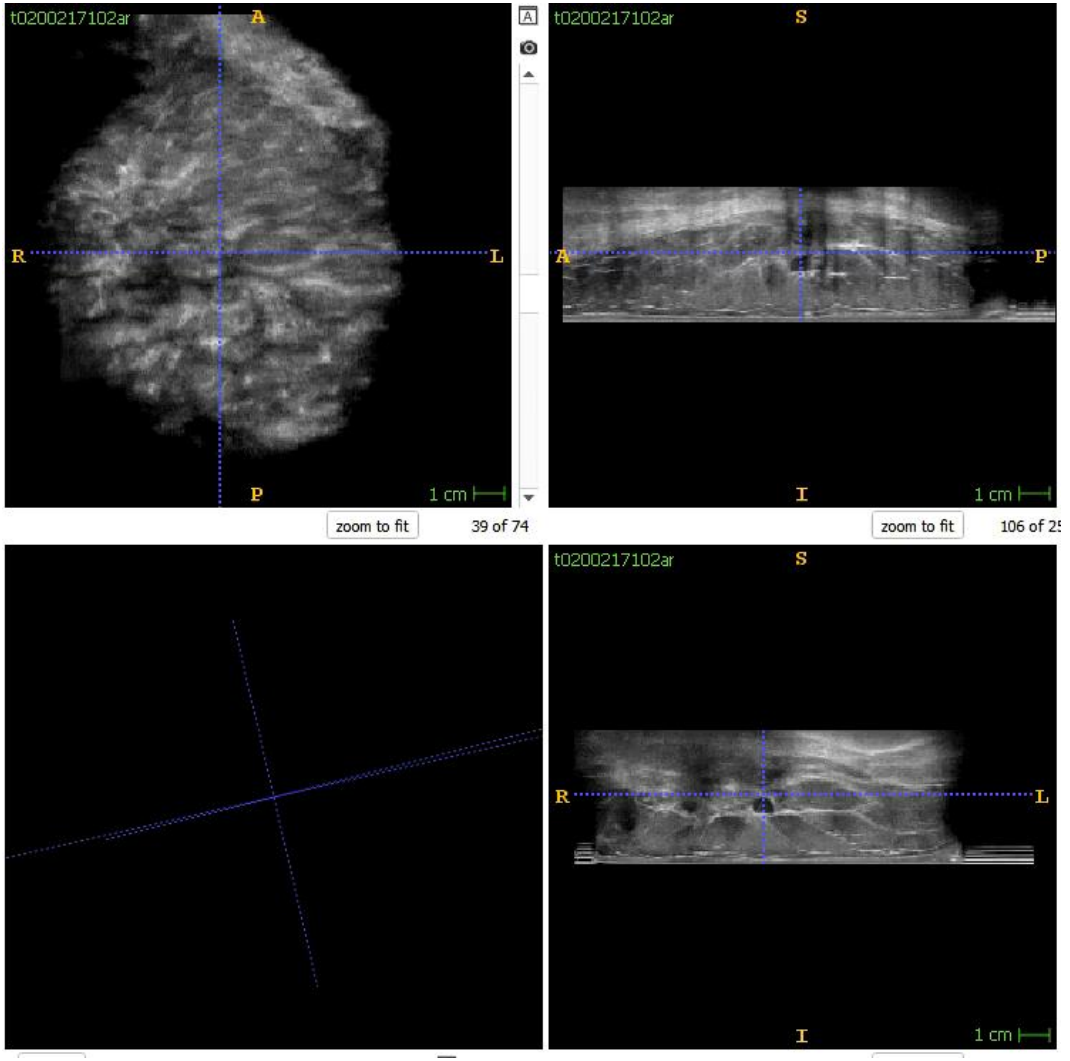







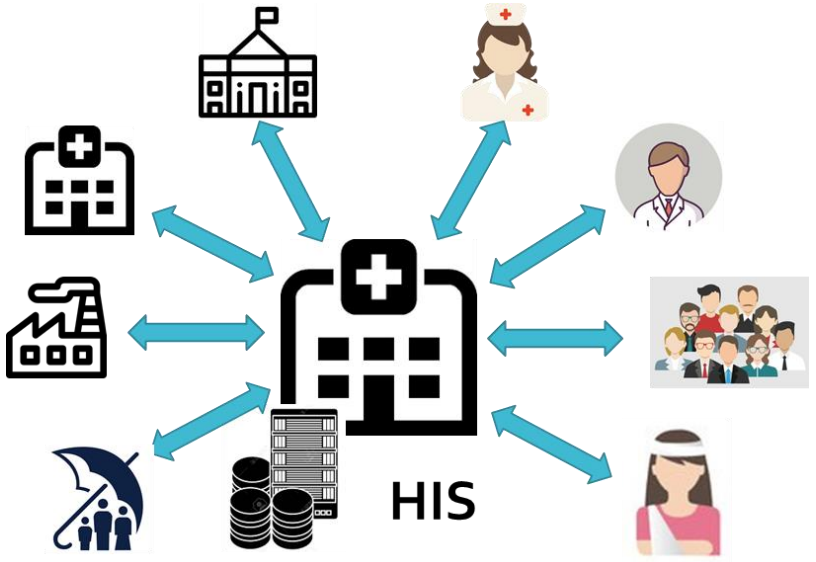
# Breast imaging

- 3D ultrasound

# Information in the hospital

- HIS. Hospital Information System.
  - Clinical patient information
  - Prescriptions
  - Operating room management
  - Patient management
  - Logistics
  - Financing
  - Public administration
  - Softwares: SAP, Costaisa, HP




  - Protocol: HL7, DICOM, XML, Webservices, etc.

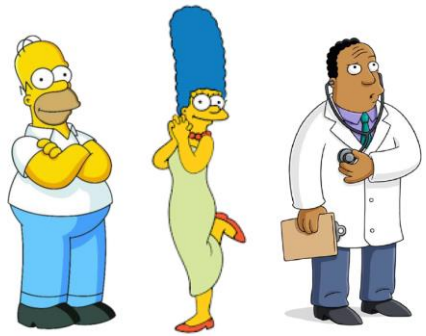
- RIS / PACS / DICOM ?

# HL7

- Interoperability standard
- Technology and platform independent
- http://www.hl7.org/
- Patient information interchange standard based on special characters separation.

```
MSH|^~\&|EPIC|SYS|HOSP|ADT|201502031126|SEC|ADT^A01|001199|P|2.3
EVN|A01|201502031126
PID|||12001||SIMPSON^HOMER||19670824|M|||742 Evergreen Terrace St. ^^ Springfield ^ OR
^ 90020 ^ USA|||||||
NK1|1|SIMPSON^MARGE|WIFE|||||NK
PV1|1|I|2000^2012^01||||11277^HIBBERT^JULIUS^J|||SUR||-||ADM|A0-
AL1|1||^Penicillin||Hives
```

- **PID**: patient ID
- **NK1**: next of kin
- **PV1**: patient visit
- **AL1**: allergies

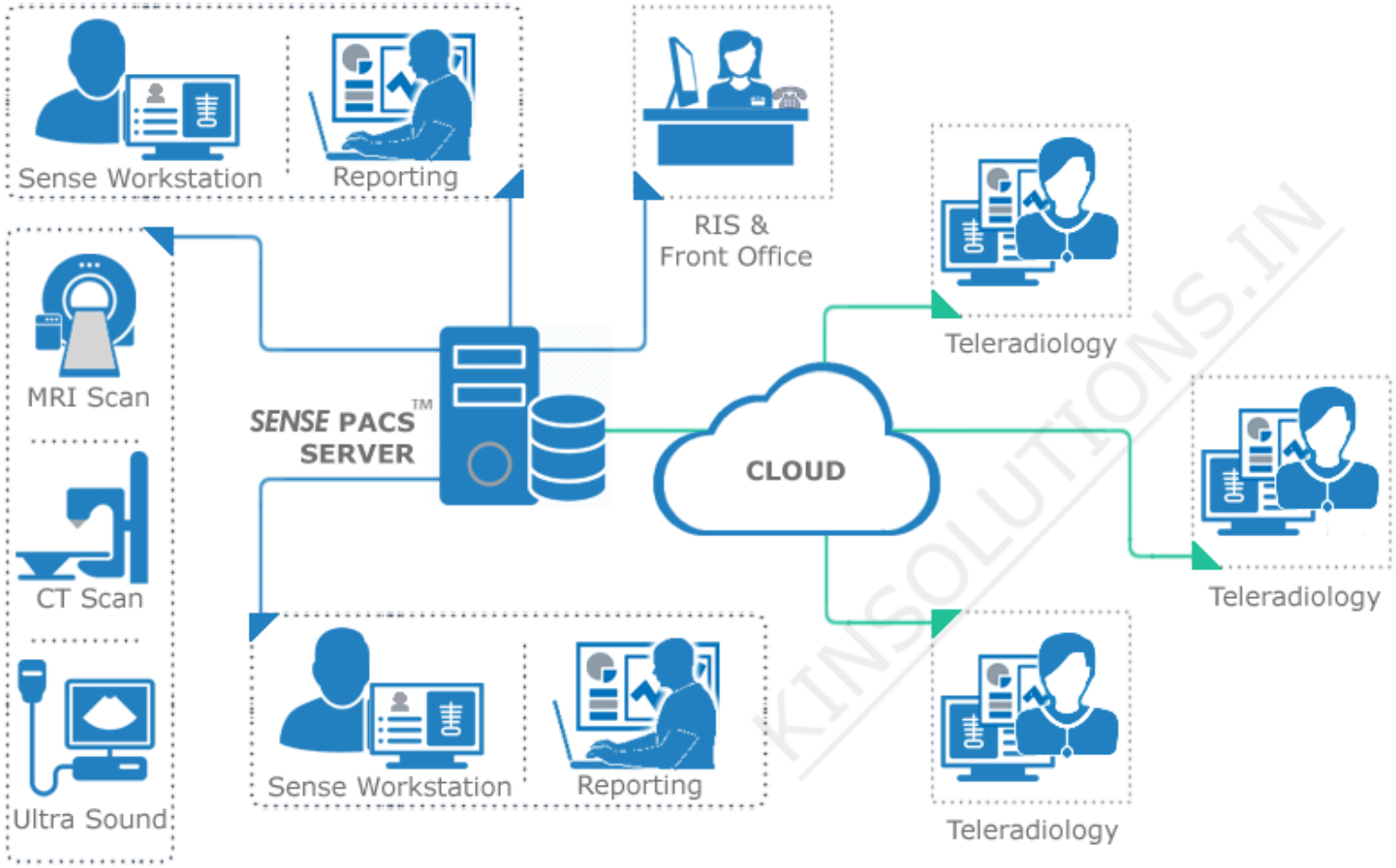


# IHE

- Integrating the Healthcare Enterprise
- Coordinated by the Radiological Society of North America (RSNA).
- Consortium between companies and public health organisations for improving interconnectivity in healthcare systems https://www.ihe.net/

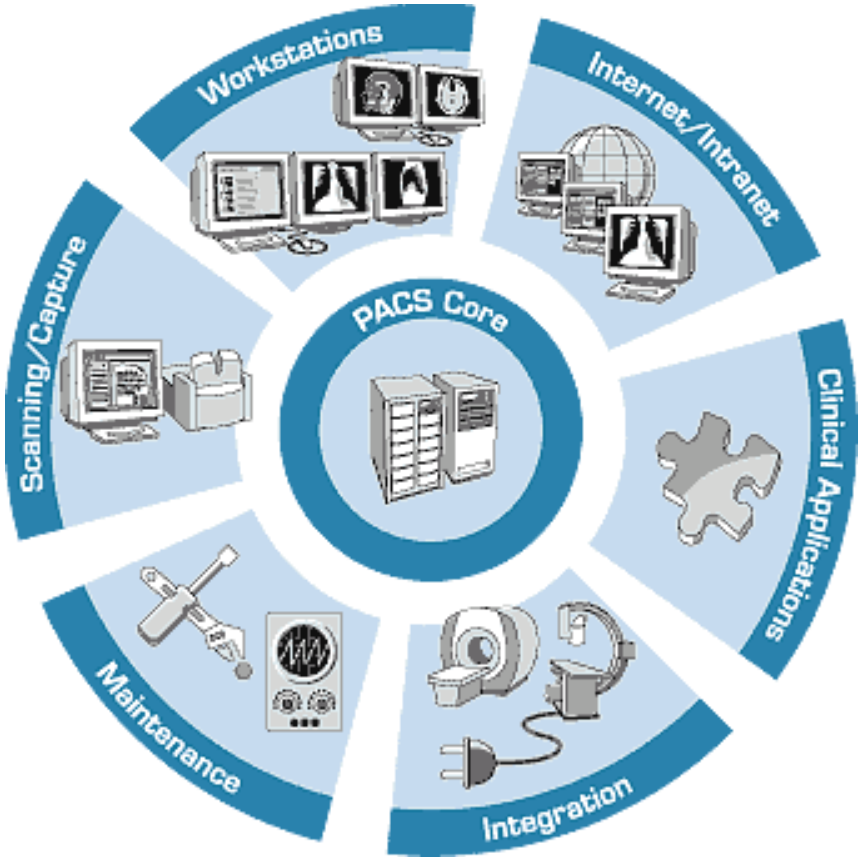
# RIS / PACS / DICOM

- Radiology Information System (RIS)
- Picture Archiving and communication system (PAC)

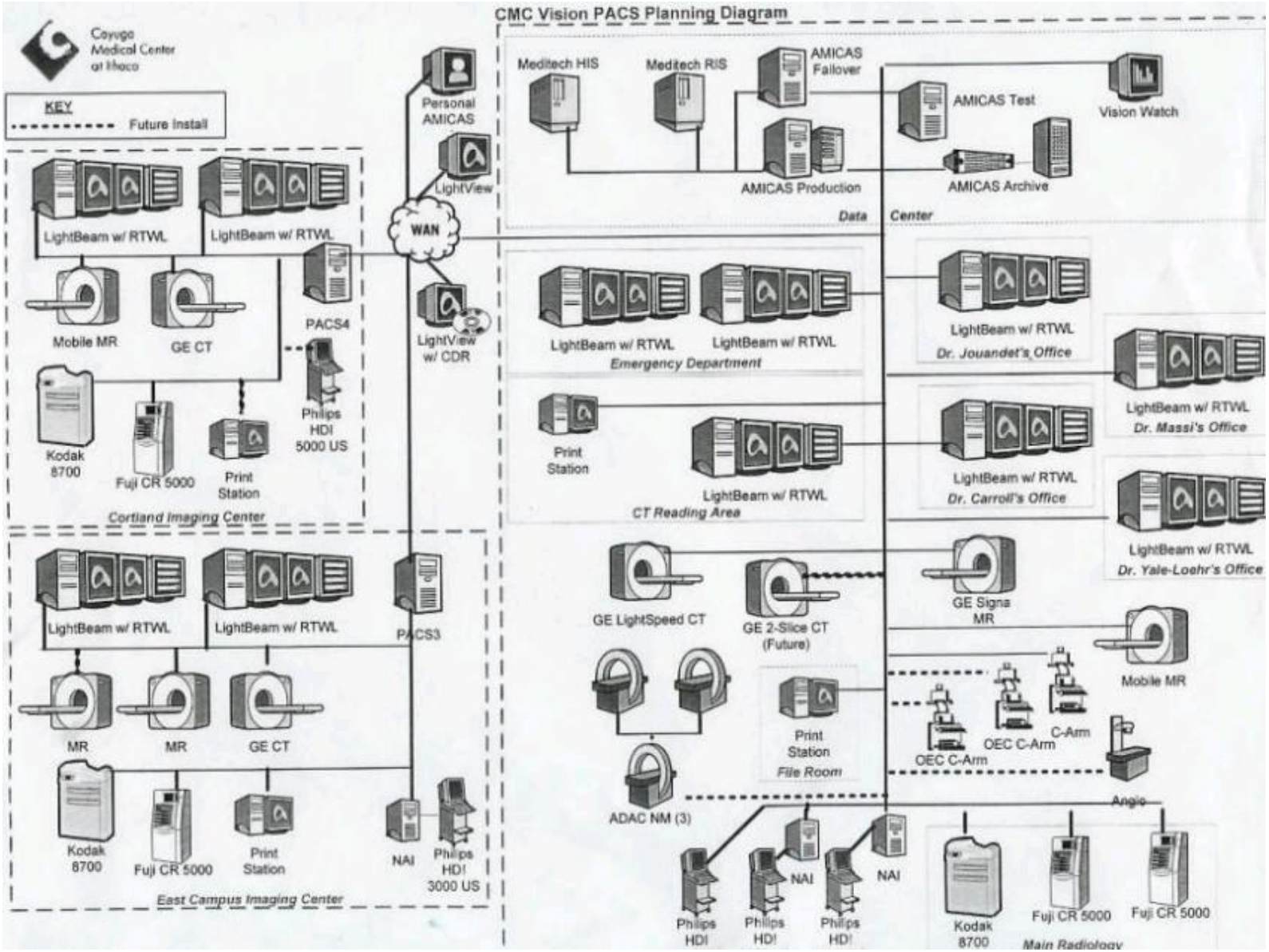


# DICOM

- DICOM: Digital Imaging and COmmunications in Medicine
- PACS: Picture Archiving and Communication System



# DICOM & PACS


CMC Vision PACS Planning Diagram
Cayuga Medical Center at Ithaca
KEY
Future Install
Personal AMICAS
LightView
WAN
LightView w/ CDR
LightBeam w/ RTWL
LightBeam w/ RTWL
Mobile MR
GE CT
PACS4
Philips HDI 5000 US
Kodak 8700
Fuji CR 5000
Print Station
Cortland Imaging Center
LightBeam w/ RTWL
LightBeam w/ RTWL
PACS3
MR
MR
GE CT
Kodak 8700
Fuji CR 5000
Print Station
NAI
Philips HDI 3000 US
East Campus Imaging Center
Meditech HIS
Meditech RIS
AMICAS Failover
AMICAS Production
AMICAS Test
Vision Watch
AMICAS Archive
Data Center
LightBeam w/ RTWL
LightBeam w/ RTWL
Emergency Department
LightBeam w/ RTWL
Dr. Jouandet's Office
LightBeam w/ RTWL
Dr. Massi's Office
Print Station
LightBeam w/ RTWL
CT Reading Area
LightBeam w/ RTWL
Dr. Carroll's Office
LightBeam w/ RTWL
Dr. Yale-Loehr's Office
GE LightSpeed CT
GE 2-Slice CT (Future)
GE Signa MR
Mobile MR
Print Station
File Room
OEC C-Arm
C-Arm
OEC C-Arm
Angio
ADAC NM (3)
NAI
NAI
Philips HDI
Philips HDI
Philips HDI
Kodak 8700
Fuji CR 5000
Fuji CR 5000
Main Radiology

# DICOM

- Digital Imaging and Comunications in Medicine.
- Proposed by  the American College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA)


https://www.dicomstandard.org/

- Standard to manage, store, print, and communicate medical imaging information and related data.
- Image format but also communication protocol

http://www.dclunie.com/dicom-status/status.html

# DICOM origins

- 1982: ACR-NEMA Committee formed
- 1983: ACR-NEMA meeting
- 1985: ACR-NEMA version 1.0
  - 1st data saving in media and communication between non-proprietary soft
- 1988: ACR-NEMA version 2.0
  - Terminology, data structure and encoding.
- **1992: ACR-NEMA version 3.0 or DICOM**
  - Rely on ISO/OSI model and use of TCP/IP protocol.
  - Unique identifiers (GGGG, NNNN).
- Supplements
  - **Suppl. 28 Grayscale Standard Display Function (GSDF), 1998**
    - Zoom, windowing, or annotations

http://www.dclunie.com/dicom-status/status.html

# DICOM origins

| Title | Format (see Key below) | | | | | |
|---|---|---|---|---|---|---|
| | PDF | HTML | CHTML | DOCX | ODT | XML |
| DICOM Part 1: Introduction and Overview | | | | | | |
| DICOM Part 2: Conformance | | | | | | |
| DICOM Part 3: Information Object Definitions | | | | | | |
| DICOM Part 4: Service Class Specifications | | | | | | |
| DICOM Part 5: Data Structures and Encoding | | | | | | |
| DICOM Part 6: Data Dictionary | | | | | | |
| DICOM Part 7: Message Exchange | | | | | | |
| DICOM Part 8: Network Communication Support for Message Exchange | | | | | | |
| DICOM Part 10: Media Storage and File Format for Media Interchange | | | | | | |
| DICOM Part 11: Media Storage Application Profiles | | | | | | |
| DICOM Part 12: Media Formats and Physical Media for Media Interchange | | | | | | |
| DICOM Part 14: Grayscale Standard Display Function | | | | | | |
| DICOM Part 15: Security and System Management Profiles | | | | | | |
| DICOM Part 16: Content Mapping Resource | | | | | | |
| DICOM Part 17: Explanatory Information | | | | | | |
| DICOM Part 18: Web Services | | | | | | |
| DICOM Part 19: Application Hosting | | | | | | |
| DICOM Part 20: Imaging Reports using HL7 Clinical Document Architecture | | | | | | |
| DICOM Part 21: Transformations between DICOM and other Representations | | | | | | |
| DICOM Part 22: Real-Time Communication | | | | | | |
| DICOM Parts 1-22: Bulk Download | | | | Zip file for each format | | |

https://www.dicomstandard.org/current

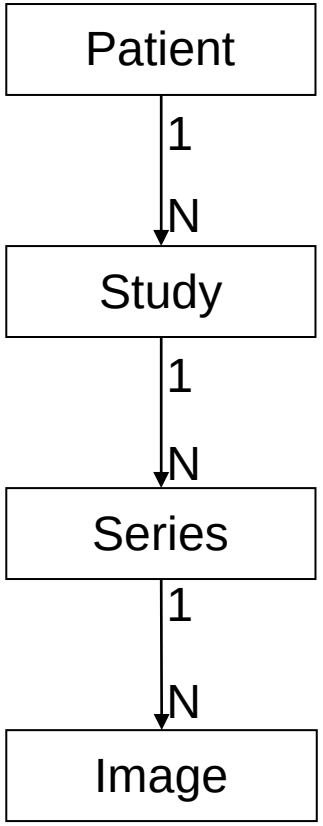
# What's in the DICOM?

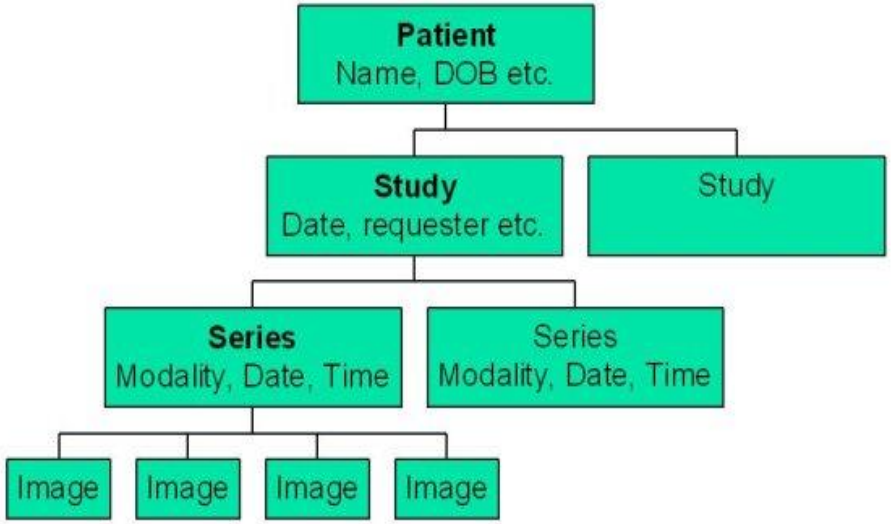
- Patient information
  - Patient: name,age , ...
  - Image acquisition: system,parameter, organ, who, where,….
  - Image information: resolution, spacing, ...
  - Image or Images
  - …

- But it is also a **communication** protocol between machines, PACs, workstations, etc.

# What's in the DICOM?

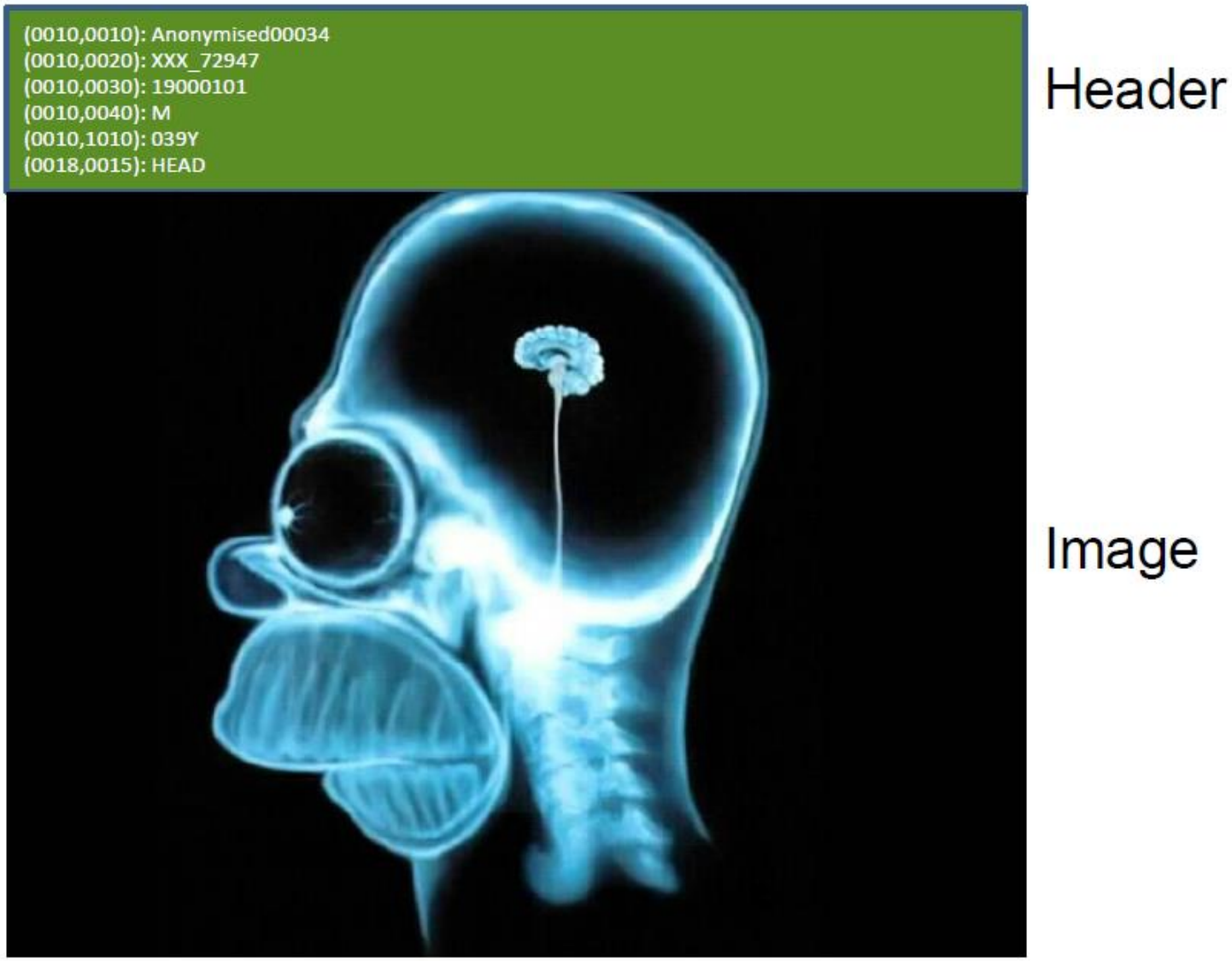
- Hierarchical structure



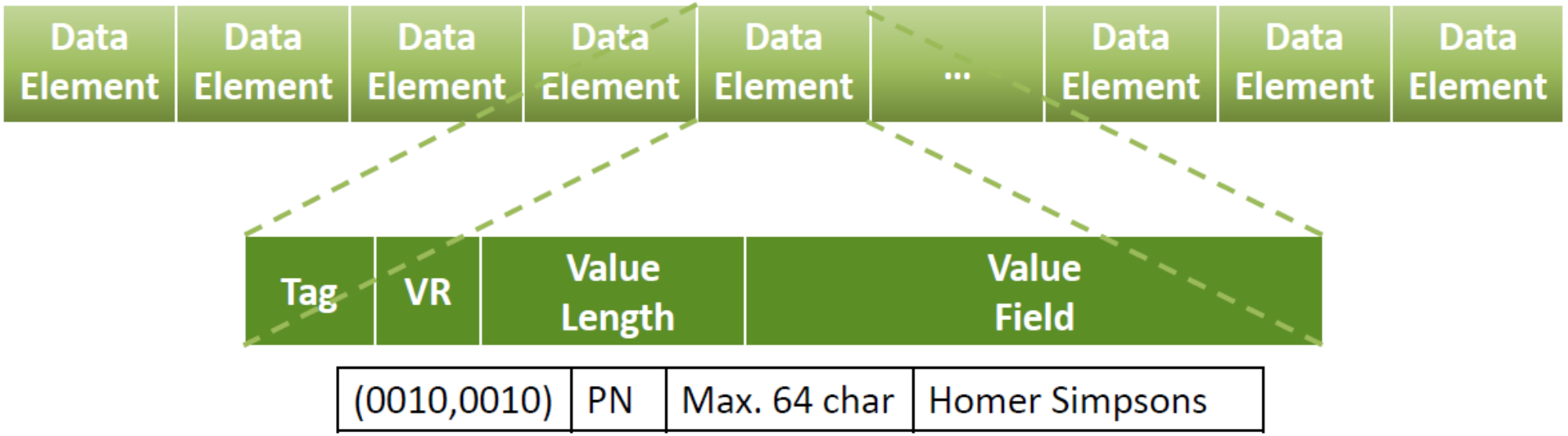



# DICOM file

**File extension**: .dcm



# DICOM file




| | |
|---|---|
| **Data Tag Element** | 16-bits unsigned representing Group and Element number. |
| **Value Representation (VR)** | 2 bytes characters containing the VR of Data Element (e.g. string) |
| **Value Length** | - 16 or 32-bit (explicit or implicit) unsigned int containing length of the Value Field.<br>- 32-bit length. Used for certain VR (SQ, UN, OW, OB) |
| **Value Field** | Even number of bytes containing the value(s) of Data Element |

# DICOM file

| VR | Definition | Length | Sample |
|---|---|---|---|
| AS | Age string | 4 bytes fixed | 047Y |
| CS | Code string | 16 bytes max. | MG |
| DA | Date string | 8 bytes fixed | 19930822 |
| DS | Decimal string | 16 bytes max. | 44.8 |
| LO | Long string | 64 chars. max. | 24X29 |
| PN | Person Name | 64 chars max | Simpson^Homer |
| SH | Short String | 16 chars max. | H0711151700038 |
| TM | Time | 14 bytes max. | 151850 |
| UI | Unique Identifier | 64 bytes max. | 1.2.840.10008.1.2.1 |
| US | Unsigned Short | 2 bytes fixed | 16 |

# DICOM file

| Tag / ID | Keyword | VR | Sample |
|---|---|---|---|
| (0008,0020) | StudyDate | DA | 20160711 |
| (0008,0022) | AcquisitionDate | DA | 20160711 |
| (0008,0060) | Modality | CS | MG |
| (0010,0010) | PatientName | PN | XXXXX_J9EKL8218SO7CHGZ |
| (0010,0020) | PatientID | LO | XXXXX_HX3LCLOW32528JVC |
| (0019,1025) | <HOLOGIC, Inc.> [25] | SH | FAST |
| (0028,0010) | Rows | US | 4096 |
| (0028,011) | Columns | US | 3328 |
| (0028,0030) | PixelSpacing | DS | 0.065238 / 0.065238 |
| (0028,0100) | BitsAllocated | US | 16 |

# DICOM file

- 8 bits or 16 bits?

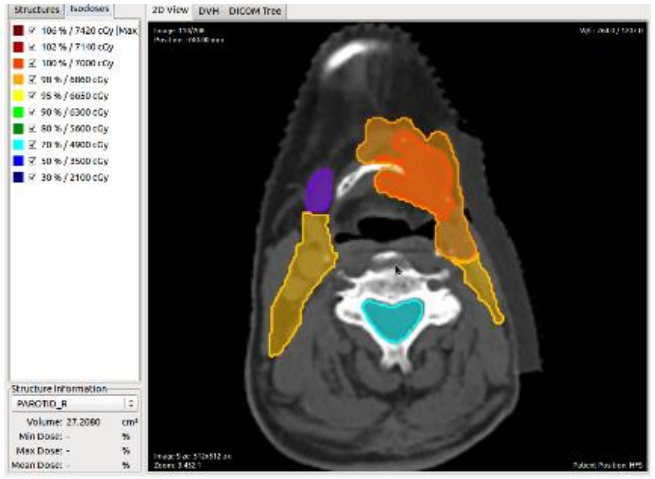
10011010011101001101100110000110101100110101011000
00110011110010110010101011110001010001100111000100
11001010100111001011110001000111010101000011010100
10010011100110100111010011011001100110000101110110
10010101011100110101100110101011000011001111001010
10010101001000110111010111100010100011001110001010
10010101001110010111100010001110101010000110101010
...

$2^8 = 256$ -> [0-255]

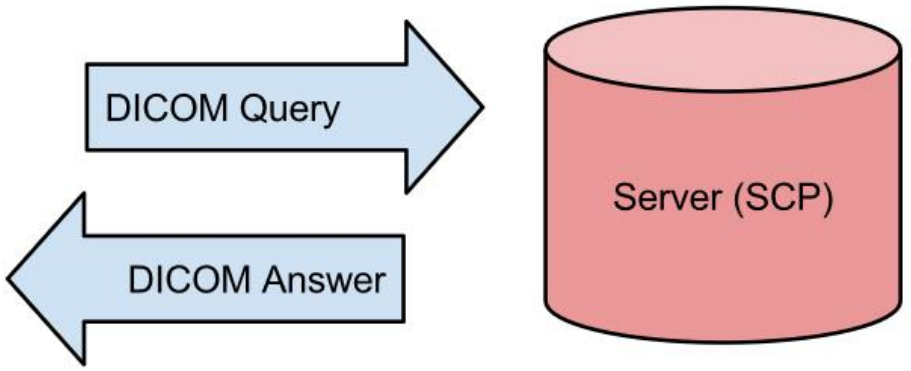
$2^{16} = 65{,}536$ -> [0-65,535]

# DICOM Protocl

- **Basic DICOM protocol actions**
  - **Test the connection** between two devices (C-Echo).
  - **Send images** from the local imaging device to a remote device (C-Store).
  - **Search the content** of a remote device (C-Find).
  - **Retrieve images** from a remote device (C-Move).
- SCU / SCP / Commands



Client (SCU)




http://book.orthanc-server.com/dicom-guide.html#dicom-echo

# dicominfo('file.dcm')

**Filename**: [1x55char]
FileModDate: '27-maig-200823: 25: 47'
FileSize: 17042728
Format: 'DICOM'
FormatVersion: 3
**Width: 2560**
**Height: 3328**
**BitDepth: 12**
**ColorType: 'grayscale'**
FileMetaInformationGroupLength: 212
FileMetaInformationVersion: [2x1uint8]
MediaStorageSOPClassUID: '1.2.840.10008.5.1.4.1.1.1.2'
MediaStorageSOPInstanceUID: [1x55char]
TransferSyntaxUID: '1.2.840.10008.1.2'
ImplementationClassUID: '1.3.6.1.4.1.5962.99.2'
ImplementationVersionName: 'PIXELMEDJAVA001'
SourceApplicationEntityTitle: 'RXMAMOPACS'
SpecificCharacterSet: 'ISO_IR100'
ImageType: 'DERIVED\PRIMARY\\RIGHT'
SOPClassUID: '1.2.840.10008.5.1.4.1.1.1.2'
SOPInstanceUID: [1x55char]
**StudyDate: '20070803**'
SeriesDate: '20070803'
**AcquisitionDate: '20070803'**
ContentDate: '20070803'
StudyTime: '120122.375000'
SeriesTime: '120334.390000'
AcquisitionTime: '120310.812000'
ContentTime: '120330.281000'
AccessionNumber: '660471'
Modality: 'MG'
**PresentationIntentType: 'FOR PRESENTATION**'
Manufacturer: 'SIEMENS'
**InstitutionName: 'HOSPITAL JOSEP TRUETA**'
InstitutionAddress: [1x27char]
**ReferringPhysicianName: [1x1struct]**
StationName: 'YBFR015811'
SeriesDescription: 'Mamobilateral, Diagnose'
InstitutionalDepartmentName: 'Department'
PerformingPhysicianName: [1x2struct]
OperatorName: [1x1struct]
**ManufacturerModelName: 'Mammomat Novation DR'**
ReferencedPerformedProcedureStepSequence: [1x1struct]
DerivationDescription: [1x42char]
SourceImageSequence: [1x1struct]
AnatomicRegionSequence: [1x1struct]
**PatientName: [1x1struct]**
**PatientID: '0000'**
**PatientBirthDate: '19560101'**
PatientSex: 'F'
PatientAge: '051Y'
ContrastBolusAgent: ''
BodyPartExamined: 'BREAST'
KVP: 25
DeviceSerialNumber: '1036'
SoftwareVersion: [1x47char]

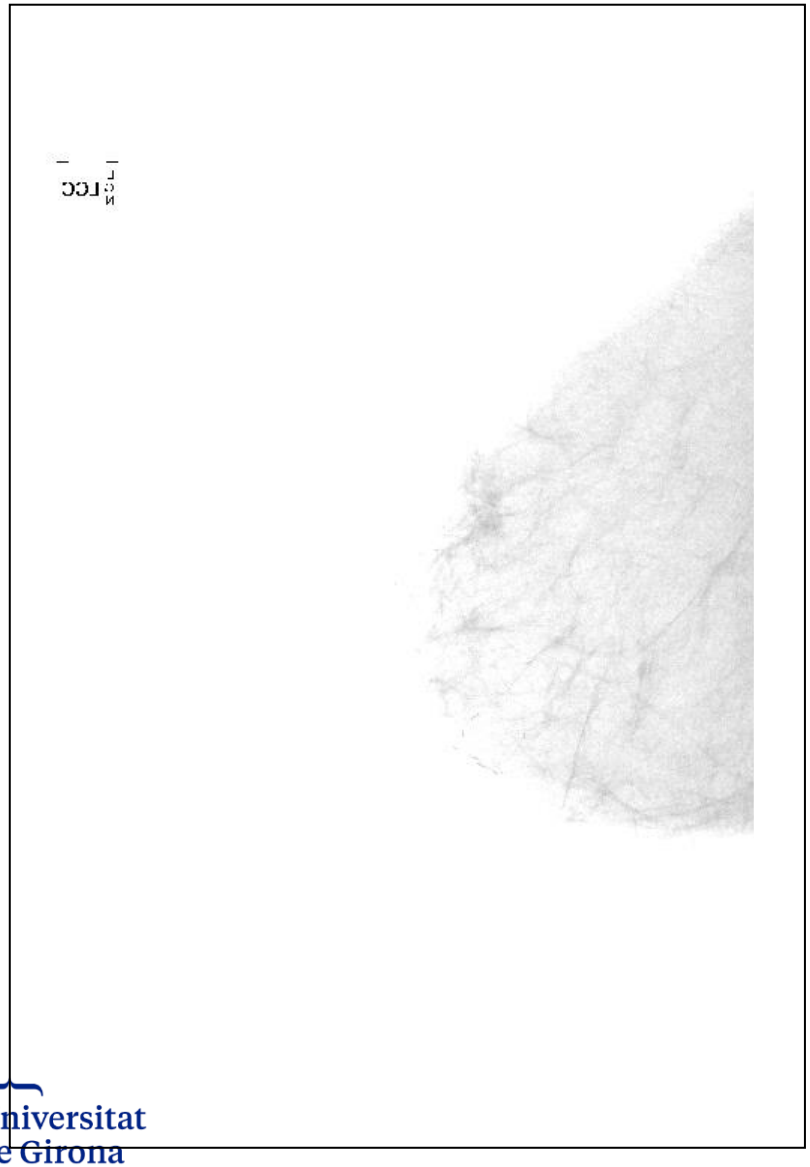
# dicominfo('file.dcm')... cont

**DistanceSourceToDetector: 650**
DistanceSourceToPatient: 636
TableAngle: 0
TableType: 'NONE'
FieldOfViewShape: 'RECTANGLE'
FieldOfViewDimensions: [2x1double]
**ExposureTime: 410**
XrayTubeCurrent: 147
Exposure: 60
ExposureInuAs: 60099
RectificationType: 'CONST POTENTIAL'
ImagerPixelSpacing: [2x1double]
Grid: 'FOCUSEDPARALLEL'
FocalSpot: 0.3000
**AnodeTargetMaterial: 'TUNGSTEN'**
BodyPartThickness: 27
CompressionForce: 112
**DateOfLastCalibration: '18590101'**
TimeOfLastCalibration: '000000.000000'
AcquisitionDeviceProcessingDescription: ''
AcquisitionDeviceProcessingCode: ''
TomoLayerHeight: 0
**PositionerType: 'MAMMOGRAPHIC'**
PositionerPrimaryAngle: 0
PositionerSecondaryAngle: 0
DetectorPrimaryAngle: 0
DetectorSecondaryAngle: 0
ShutterShape: 'RECTANGULAR'
ShutterLeftVerticalEdge: 0
ShutterRightVerticalEdge: 2560
ShutterUpperHorizontalEdge: 0
ShutterLowerHorizontalEdge: 3328
ViewPosition: 'CC'
Sensitivity: 0
DetectorConditionsNominalFlag: 'YES'
DetectorTemperature: 30
**DetectorType: 'DIRECT'**
DetectorConfiguration: 'AREA'
DetectorDescription: ''
DetectorMode: 'Normalmode'
DetectorID: 'MP1775'
DateOfLastDetectorCalibration: '20070724'
TimeOfLastDetectorCalibration: '082552.265000'
**ExposuresOnDetectorSinceLastCalibration: 23702**
ExposuresOnDetectorSinceManufactured: 57839
DetectorTimeSinceLastExposure: 920.1090
DetectorActiveTime: 410
DetectorActivationOffsetFromExposure: 0
DetectorBinning: [2x1double]
DetectorElementPhysicalSize: [2x1double]
DetectorElementSpacing: [2x1double]
DetectorActiveShape: 'RECTANGLE'
DetectorActiveDimensions: [2x1double]
DetectorActiveOrigin: [2x1double]
FieldOfViewOrigin: [2x1 double]
FieldOfViewRotation: 0
FieldOfViewHorizontalFlip: 'NO'
**FilterMaterial: 'RHODIUM'**

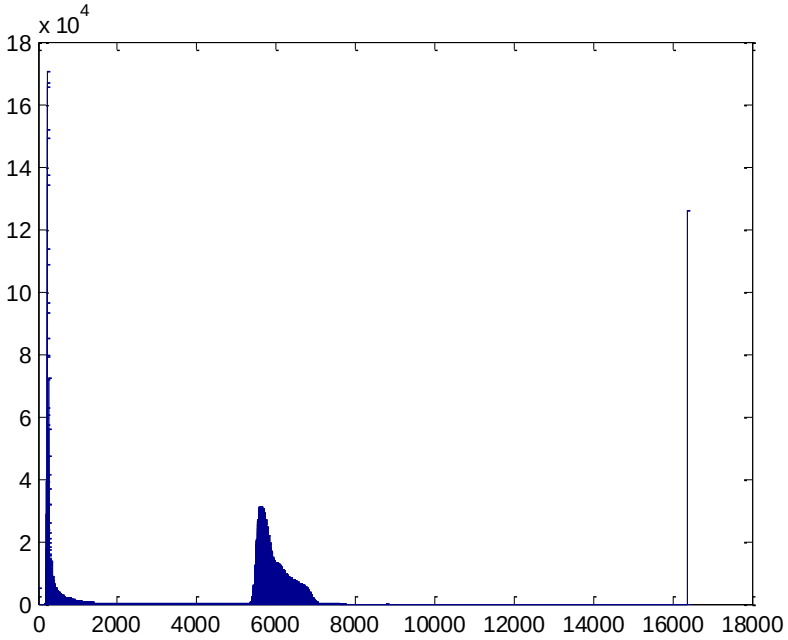
# dicominfo('file.dcm')... cont

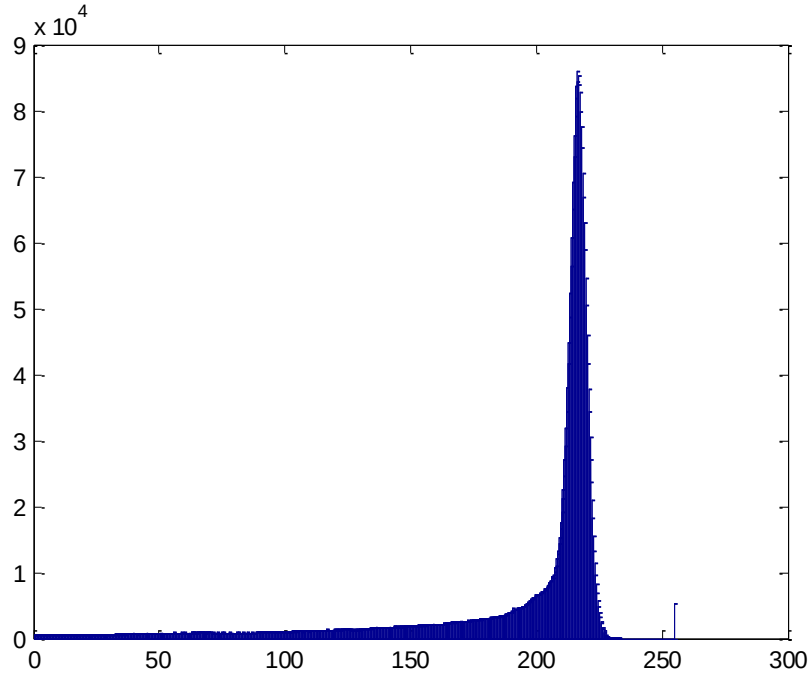
FilterThicknessMinimum: 0.0500
FilterThicknessMaximum: 0.0500
**ExposureControlMode: 'AUTOMATIC'**
ExposureControlModeDescription: [1x55char]
ExposureStatus: 'NORMAL'
ExposureTimeInuS: 410000
XrayTubeCurrentInuA: 1.4658e+005
**StudyInstanceUID: [1x55char]**
**SeriesInstanceUID: [1x55char]**
StudyID: '1'
SeriesNumber: 2
AcquisitionNumber: 1
InstanceNumber: 1
PatientOrientation: 'P\L'
**ImageLaterality: 'R'**
ImageComments: ''
SamplesPerPixel: 1
PhotometricInterpretation: 'MONOCHROME2'
Rows: 3328
Columns: 2560
BitsAllocated: 16
BitsStored: 12
HighBit: 11
PixelRepresentation: 0
QualityControlImage: 'NO'
BurnedInAnnotation: 'NO'
**PixelIntensityRelationship: 'LOG'**
PixelIntensityRelationshipSign: 1
**WindowCenter: [2x1double]**
**WindowWidth: [2x1double]**
RescaleIntercept: 0
RescaleSlope: 1
RescaleType: 'US'
ImplantPresent: 'NO'
PartialView: 'NO'
CalibrationImage: 'NO'
ViewCodeSequence: [1x1struct]
HistogramSequence: [1x1struct]
Private_0095_10xx_Creator: 'SIENET'
Private_0095_100c: [4x1uint8]
PresentationLUTShape: 'IDENTITY
WindowCenterWidthExplanation: 'WINDOW1\WINDOW2'
LossyImageCompression: '00'
Private_0029_10xx_Creator: 'SIEMENS MEDCOM HEADER'
Private_0029_11xx_Creator: 'SIEMENS MEDCOM HEADER2'
**Private_0029_1031**: [12x1uint8]
**Private_0029_1032**: [4x1uint8]
**Private_0029_1033**: [4x1uint8]
**Private_0029_1034**: [12x1uint8]
Private_0029_1160: [4x1uint8]
StudyPriorityID: 'MED'
PerformedProcedureStepStartDate: '20070803'
PerformedProcedureStepStartTime: '120122.375000'
PerformedProcedureStepID: 'MG20070803120122'
EntranceDose: 0
DistanceSourceToEntrance: 609
OrganDose: 0.0070
**OrganExposed: 'BREAST'**
AcquisitionContextSequence: [1x1struct]
EntranceDoseInmGy: 2
Private_0041_10xx_Creator: 'SIEMENSMEDSPDXMGWHAWS1'
Private_0041_1002: [10x1uint8]

# dicomread('file.dcm')



# dicomread('file.dcm')



# To have in mind...

- Data protection! We are dealing with personal data!

  http://plastimatch.org/dicom_comparison.html

- Image formats. 2D, 3D, 4D.
- Information visualization
- Bit depth: 8, 12, 16?
- Dimensionality, resolution,…
- Other formats: http://www.itk.org/Wiki/ITK/File_Formats
  - nrrd (Nearly Raw raster data http://teem.sourceforge.net/nrrd/)
  - mhd (meta image)
  - Analyze, etc...

# DICOM Viewers

- OsiriX
- Dicomworks
- MicroDicom
- JiveX DICOM Viewer
- 3DimViewer
- Mango
- Escape
- IRFANVIEW
- RadiAnt
- HOROS
- Itk Snap

# To know more

- https://www.dicomstandard.org/ Official Site
- https://en.wikipedia.org/wiki/DICOM
- Itk.org
- Insight into images