

On the use of DICOM as a storage layer for STL and IIF

Sébastien Jodogne





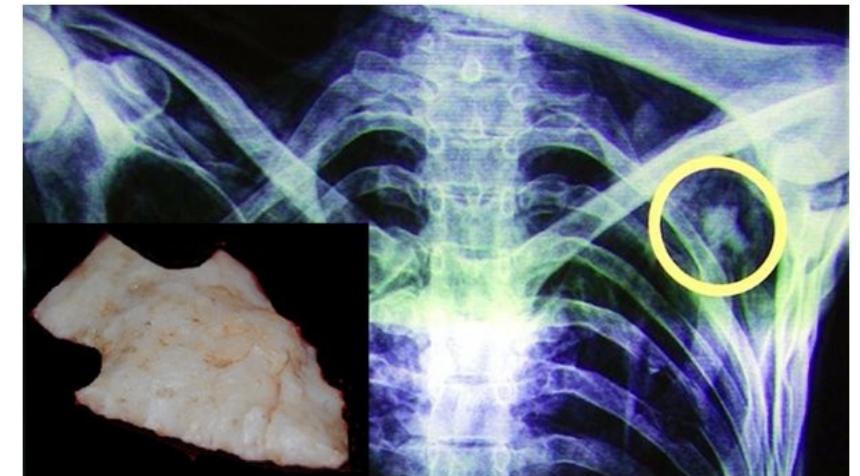
On the use of Orthanc for cultural heritage

Sébastien Jodogne

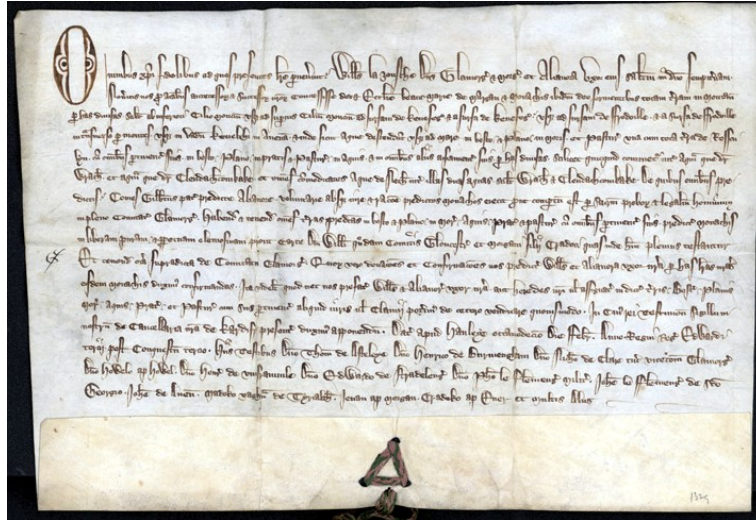


Cultural heritage

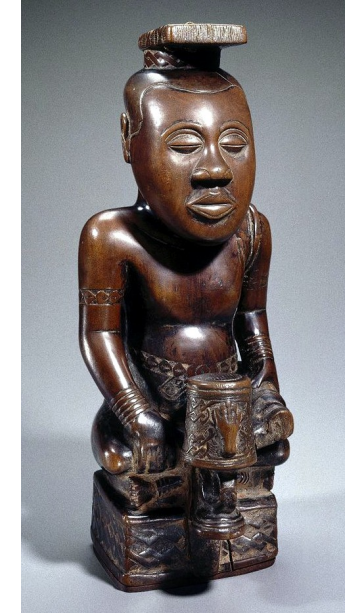
Long-term preservation of images



Other human artifacts to be imaged



Venus of Hohle Fels



Canopic jars



0 2 cm.



Also in life sciences



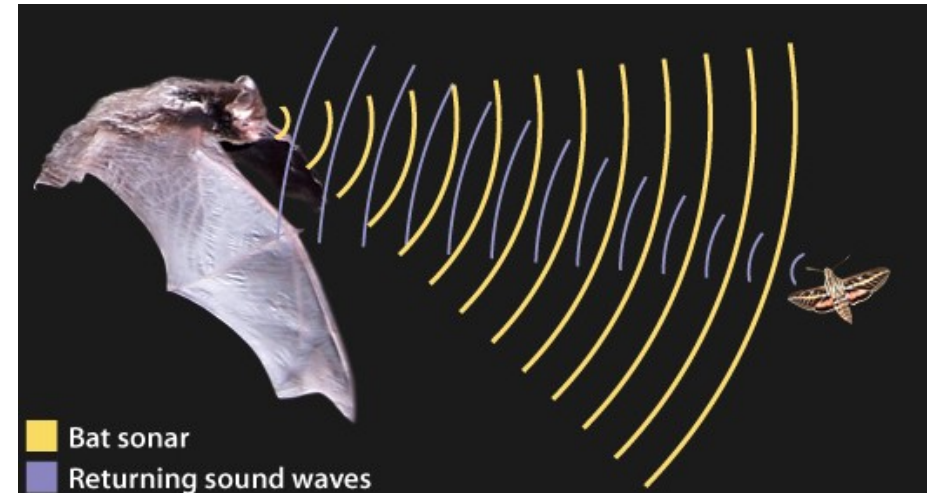
Graphosoma lineatum 1.5K 8 48



Cryptocephalus sericeus 1k 11 28



Carabus auronitens 545 0 15



Challenges

- **Many imaging modalities:** visible light, X-ray, CT, 3D models, high-resolution scans, PDF reports...
- **Huge number of file formats** (sometimes proprietary): JPEG, PNG, TIFF, WAV, STL, Nexus...
- **Many different software**, sometimes also proprietary, that most often mix storage with analysis
- **No standardization of associated metadata**
- **Long-term archival** on digital media (need for some type of indexing + sustainable formats)
- **How to share this knowledge with general audience**, notably through Web platforms?



Challenges

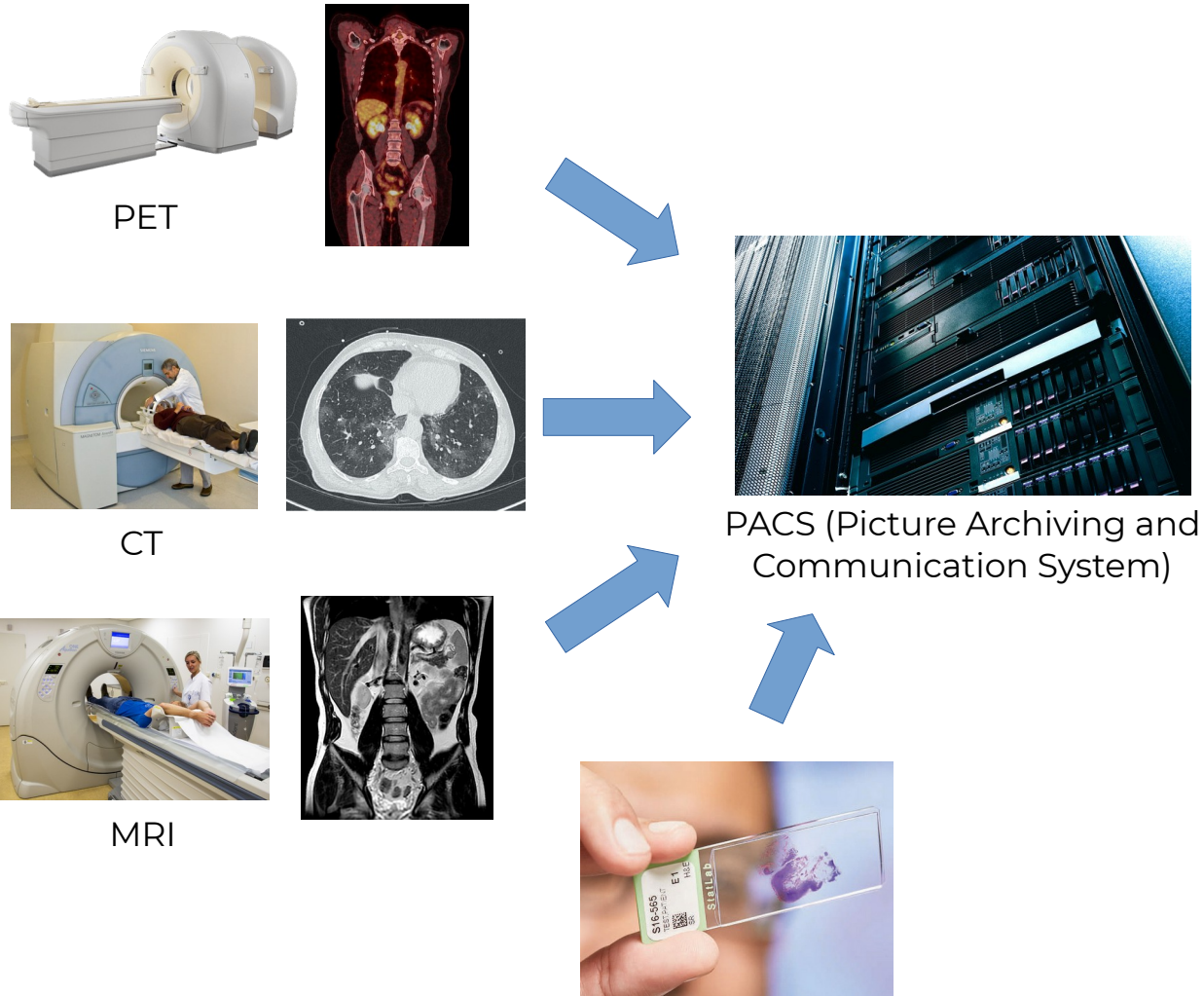
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How could free software help?

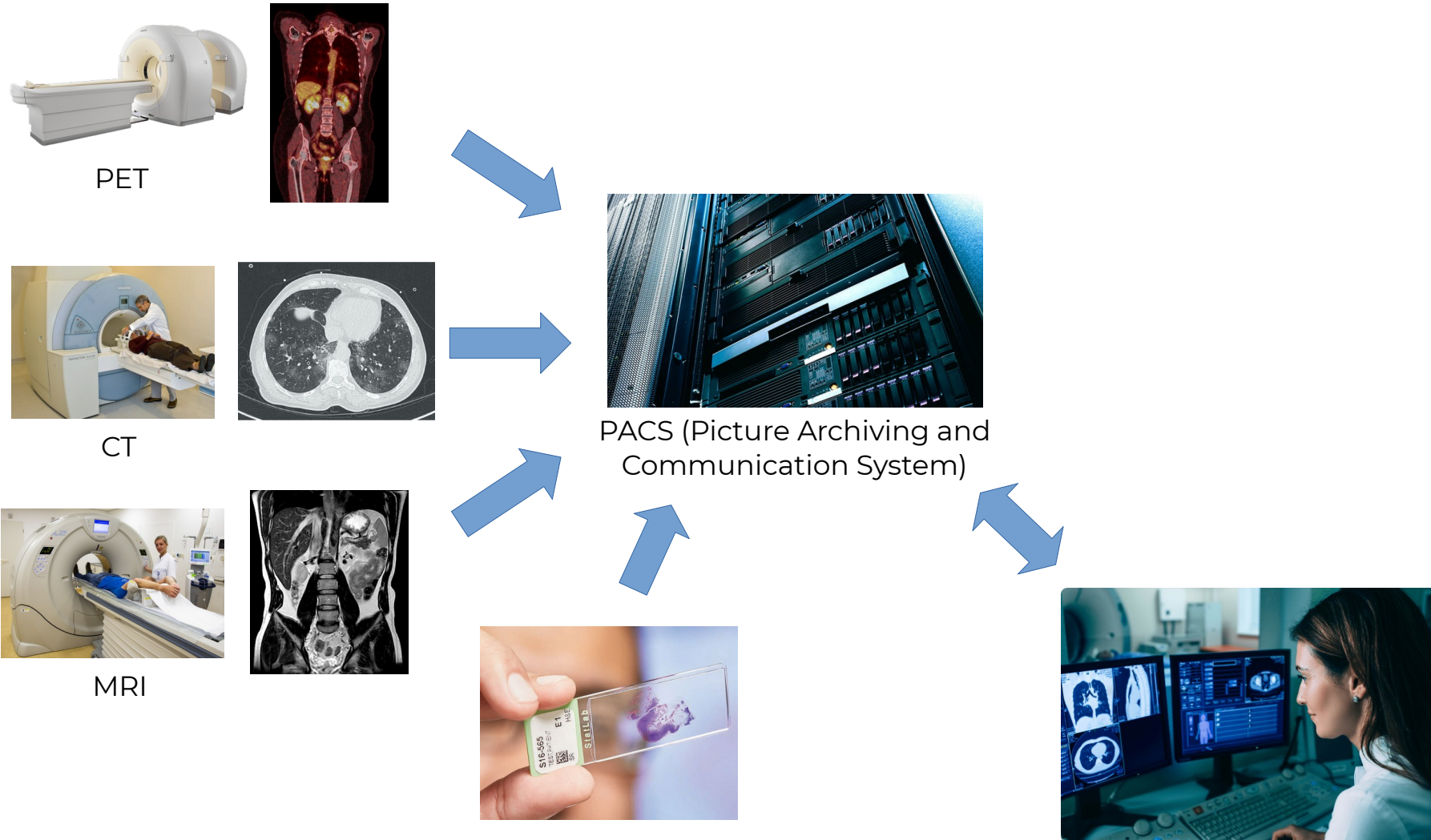


DICOM & Orthanc

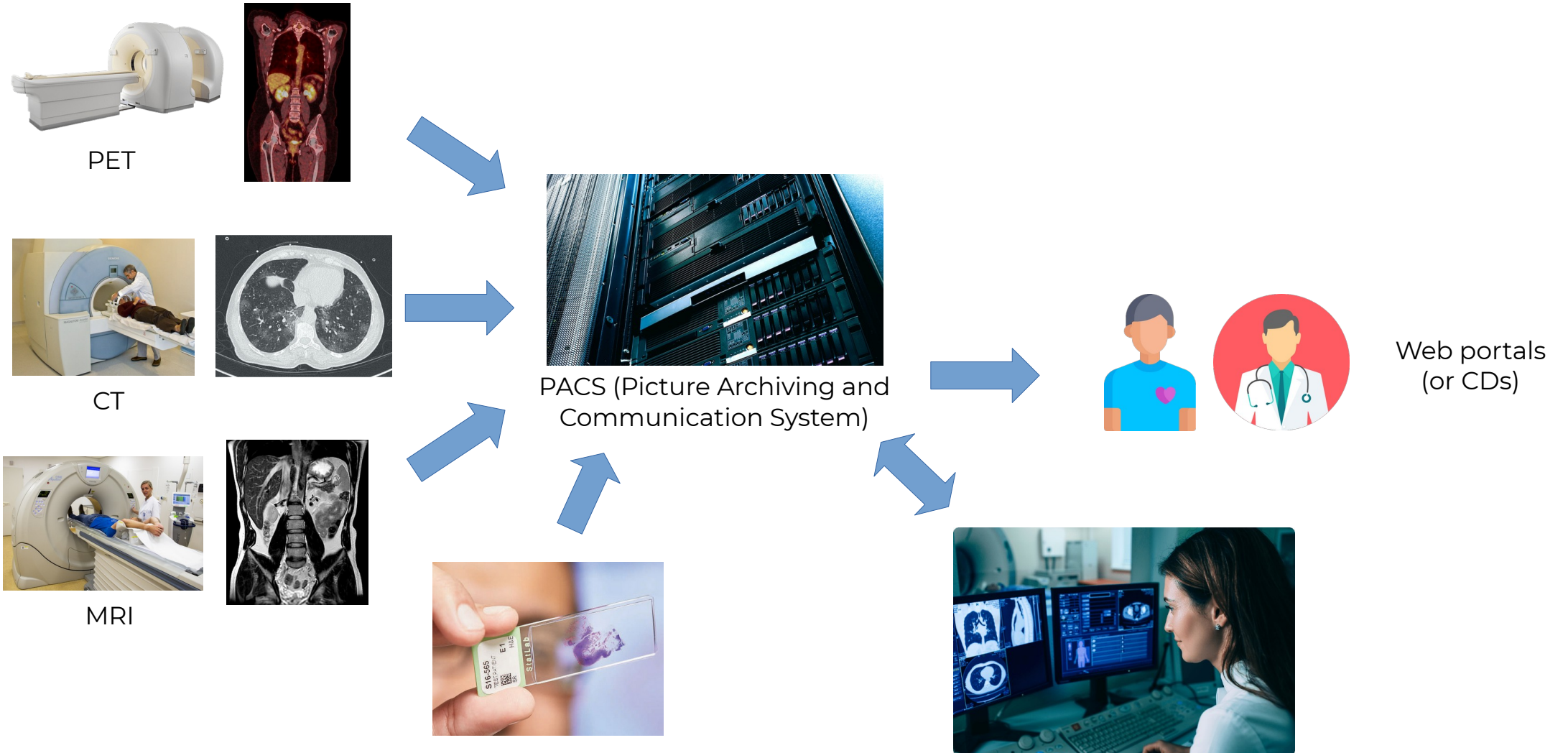
“Big imaging” inside hospitals



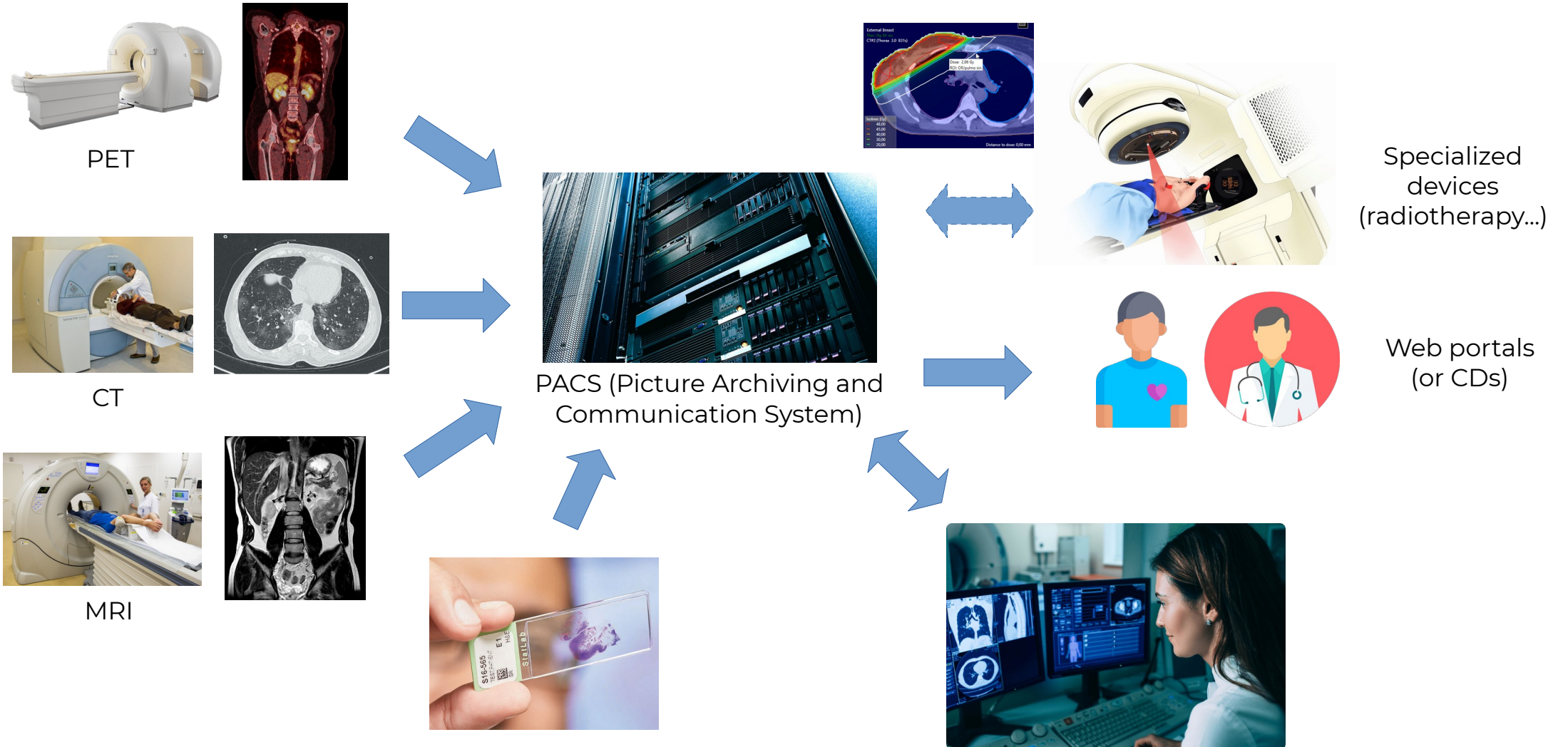
“Big imaging” inside hospitals



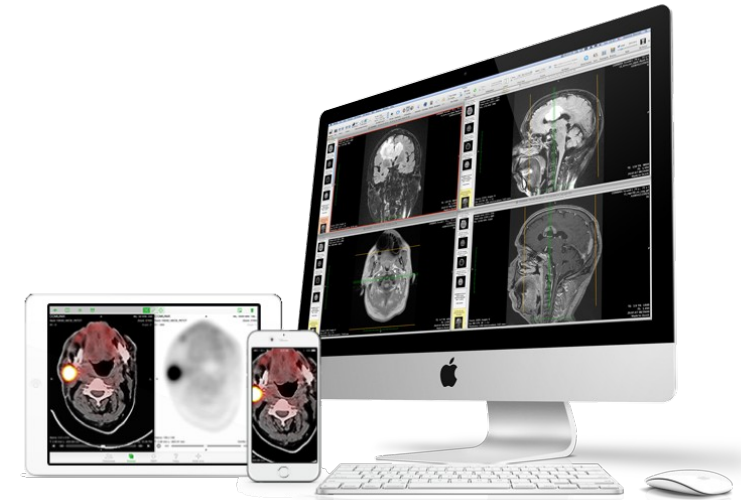
“Big imaging” inside hospitals



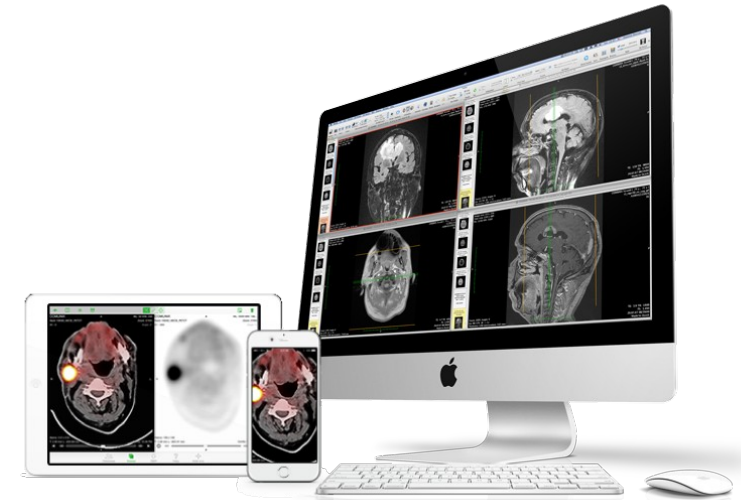
“Big imaging” inside hospitals



Everything is driven by software

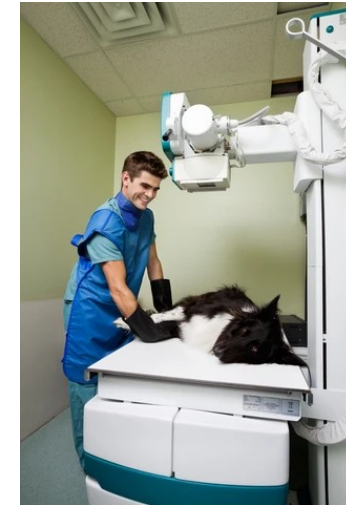
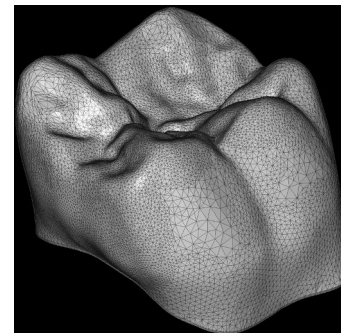
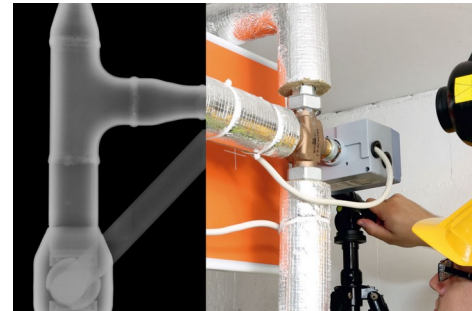
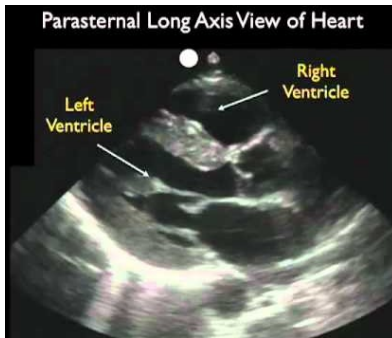


Everything is driven by software



“One **OPEN standard** to rule them all...”

Also “small imaging” and out of hospitals!



**DICOM is everywhere!
Every vendor uses it!**





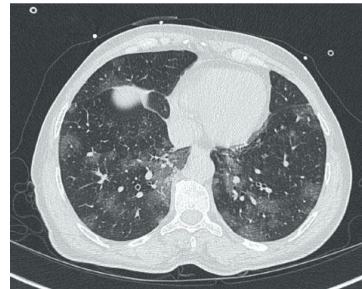
File format



Network protocol



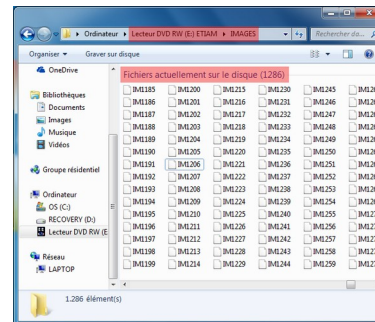
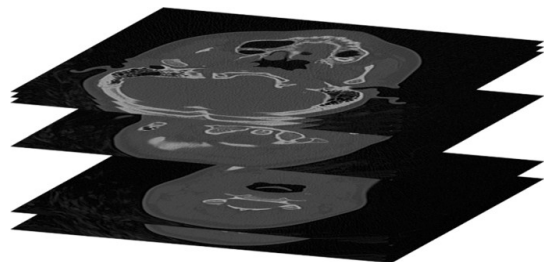
Acquisition data (kind of XML)



One slice of image (kind of PNG)



Early example of Web service: « store / query / retrieve »



Large variations in the volume of one medical image: radiography – 10MB, mammography – 100MB, CT-scan – 500MB, histology – 10GB



2011: “We want to make use of our medical images by ourselves”

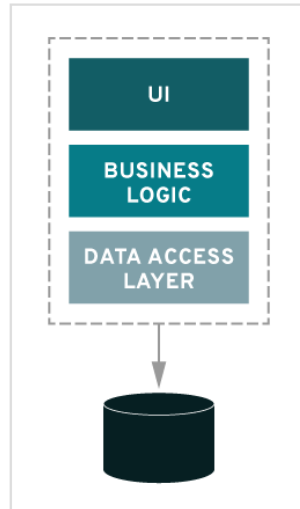


ORT[H]ANC

*2012: The first free and open-source DICOM server with a REST API that just **starts out-of-the-box***

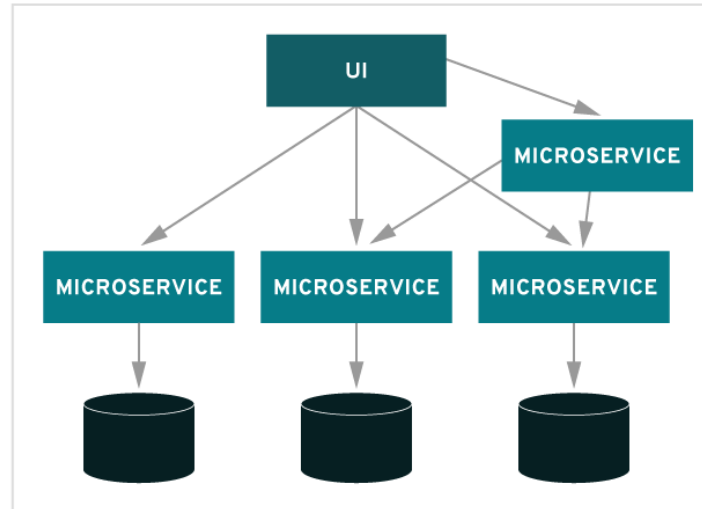
Basic ideas behind Orthanc

MONOLITHIC



VS.

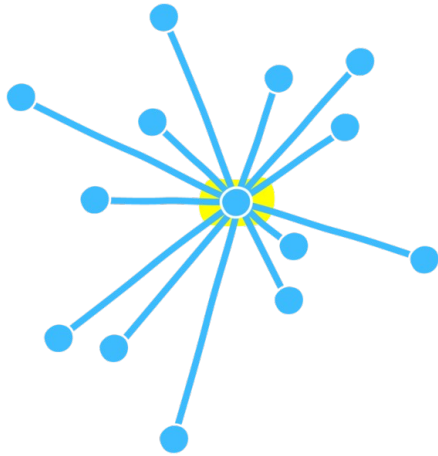
MICROSERVICES



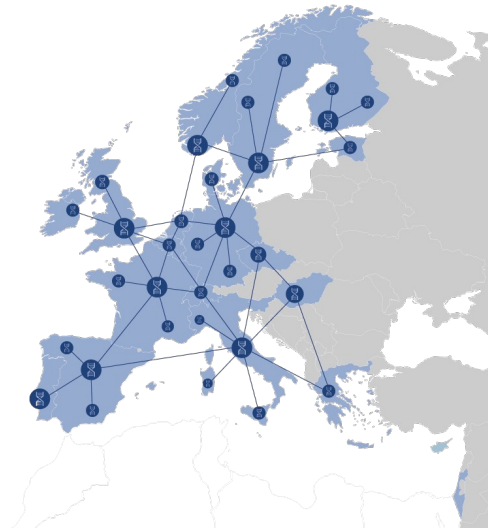
*“Let’s create a **microservice (SOA)** for medical imaging that leverages the worldwide **DICOM open standard**”*

*“Let’s release it as **free software (GPL)**, as it is our responsibility as a University to **share knowledge** and to **foster innovation**”*

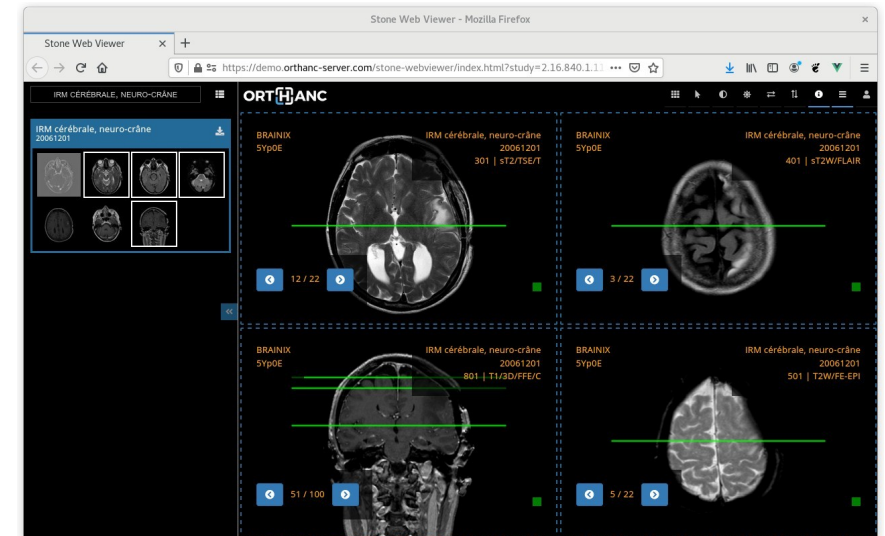
ORT^HANC



PACS, widely used for research or automation, possibly multiple instances

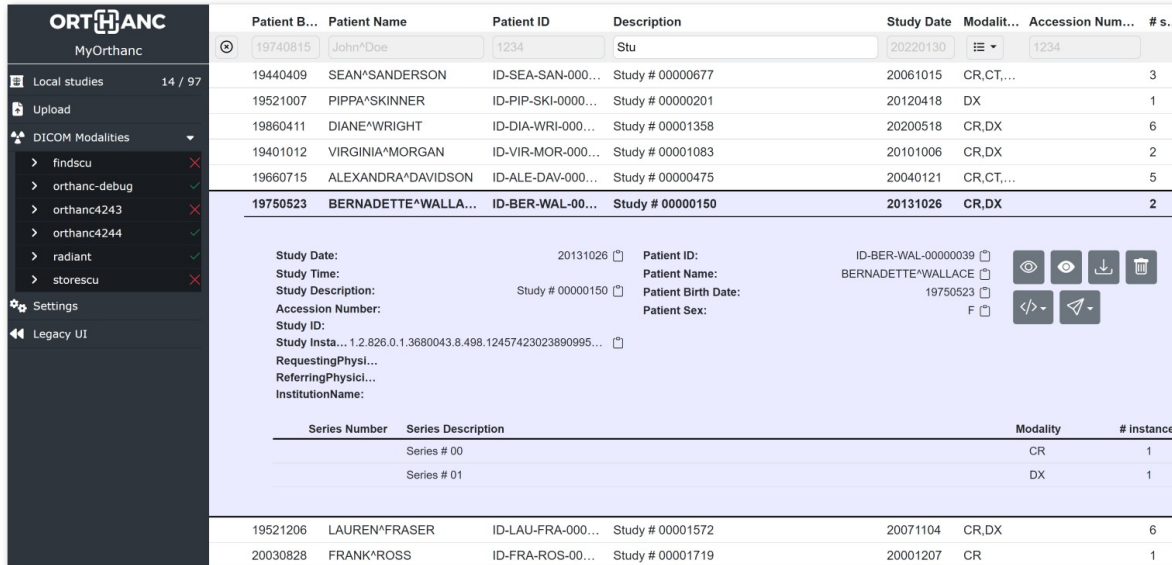


Inter-site exchanges (including to the cloud)



Teleradiology portals

Key features of Orthanc



The screenshot shows the Orthanc web interface. On the left is a sidebar with navigation options: Local studies (14 / 97), Upload, DICOM Modalities (with sub-items like findscu, orthanc-debug, etc.), Settings, and Legacy UI. The main area displays a table of patients and studies. Below the table, a detailed view for a specific study is shown, including fields for Study Date, Patient ID, Patient Name, Accession Number, and Study ID. At the bottom of this view is a table of series.

Patient B...	Patient Name	Patient ID	Description	Study Date	Modalit...	Accession Num...	# s...
19740815	John*Doe	1234	Stu	20220130		1234	
19440409	SEAN*SANDERSON	ID-SEA-SAN-000...	Study # 00000677	20061015	CR,CT,...		3
19521007	PIPPA*SKINNER	ID-PIP-SKI-0000...	Study # 00000201	20120418	DX		1
19860411	DIANE*WRIGHT	ID-DIA-WRI-000...	Study # 00001358	20200518	CR,DX		6
19401012	VIRGINIA*MORGAN	ID-VIR-MOR-000...	Study # 00001083	20101006	CR,DX		2
19660715	ALEXANDRA*DAVIDSON	ID-ALE-DAV-000...	Study # 00000475	20040121	CR,CT,...		5
19750523	BERNADETTE*WALLA...	ID-BER-WAL-00...	Study # 00000150	20131026	CR,DX		2

Series Number	Series Description	Modality	# instances
Series # 00		CR	1
Series # 01		DX	1



- Reference, **free and open-source** implementation of a DICOM server
- **Lightweight**: Focused on simplicity, portability and small footprint (C++)
- Built-in support of Web technologies (Web interface, **REST API**)
- Highly versatile, extensible and scriptable (**plugins**)
- **Industrial grade (QA), large-scale project** (over 400,000 LOCs)

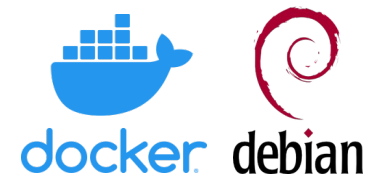


Lightweight



Rest API

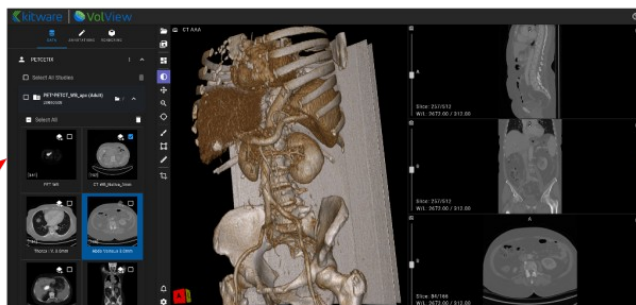
Integrated Web viewers



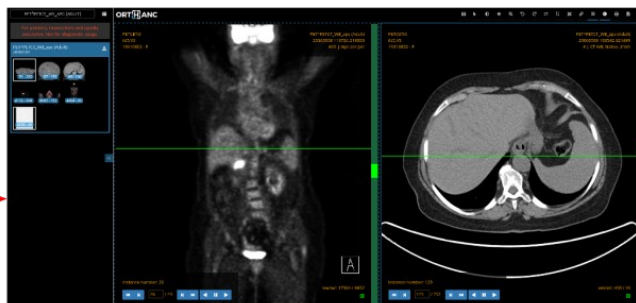
Orthanc Explorer

Orthanc Explorer interface showing patient details (PETETIX) and study information (Abdo-Velneux 3.0mm, CT WB_Native_3mm). A red box highlights the 'Open Kitware's VoView', 'Stone Web viewer', and 'Open OHIF viewer' buttons.

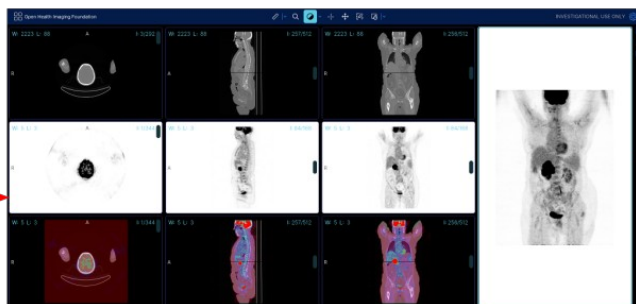
Kitware VoView



Stone Web viewer



OHIF



Orthanc Explorer 2

Orthanc Explorer 2 interface showing a table of studies and a toolbar. A red box highlights the toolbar icons.

Study	Patient Birth Date	Patient Name	Patient ID	Study Description	Study Date	Modalities In Study	Accession #	Series
19310802	John D	1234	Chest		20060508	CT,PT	0	7

Series...	Series Description	Modality	# I...
4	CT WB_Native_3mm	CT	292
7	Thorax I.V. 3.0mm	CT	134
9	Abdo-Velneux 3.0mm	CT	166
102	PET WB	PT	344
603	mpr.axial.fusion	CT	162
604	mpr.cor.fusion	CT	50
605	mpr.cor.pet	PT	49

Integrated Web viewers



Orthanc Explorer

Orthanc Explorer interface showing patient details for PETETIX and study details for PET*PETCT_WB_apc (A...). A red box highlights the 'Open Kitware's VoView', 'Stone Web viewer', and 'Open OHIF viewer' buttons.

Kitware VoView

Kitware VoView interface showing 3D anatomical models and CT slices.

Stone Web viewer

Stone Web viewer interface showing PET and CT fusion images.

OHIF

OHIF viewer interface showing multiple views of CT and PET scans.

Orthanc Explorer 2

Orthanc Explorer 2 interface showing a list of studies and a detailed view of a study. A red box highlights the 'Open Kitware's VoView', 'Stone Web viewer', and 'Open OHIF viewer' buttons in the top right corner.

Series...	Series Description	Totality	# I...
4	CT_WB_Native_3mm	CT	292
7	Thorax I.V. 3.0mm	CT	134
9	Abdo-Veineux 3.0mm	CT	166
102	PET WB	PT	344
603	mpr.axial.fusion	CT	162
604	mpr.cor.fusion	CT	50
605	mpr.cor.pet	PT	49

Radiography

Relation with cultural heritage?



Relation with cultural heritage?

CT-scans



2D X-rays



Relation with cultural heritage?

CT-scans



2D X-rays



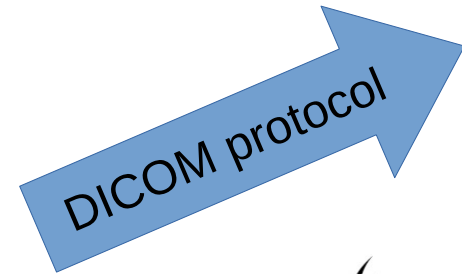
DICOM protocol

DICOM protocol

ORT  ANC

Relation with cultural heritage?

CT-scans



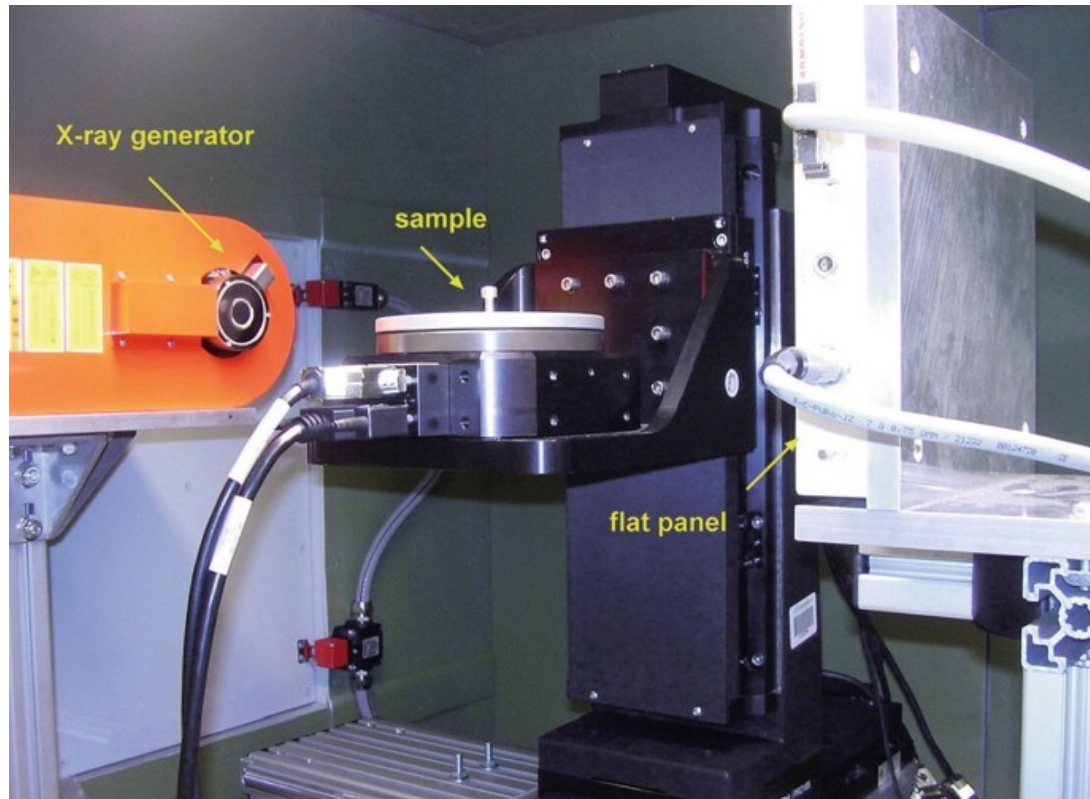
ORT  ANC

2D X-rays

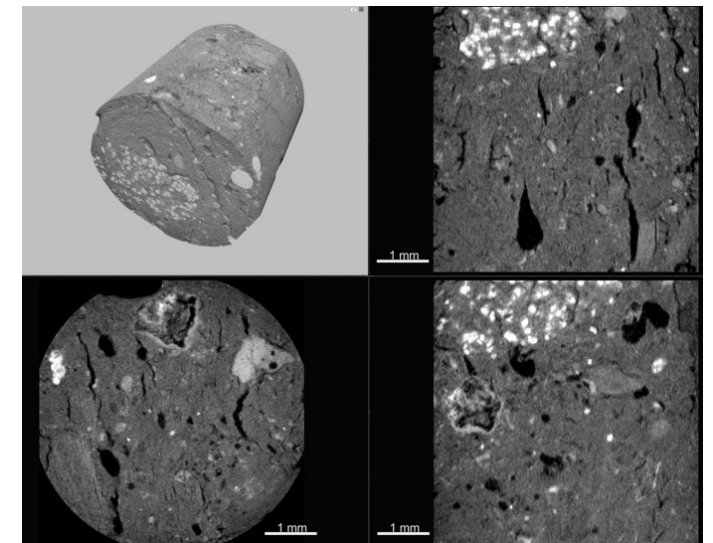
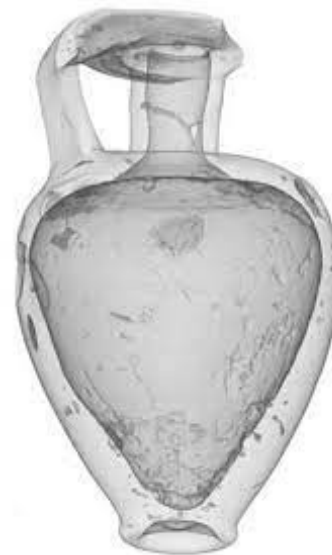
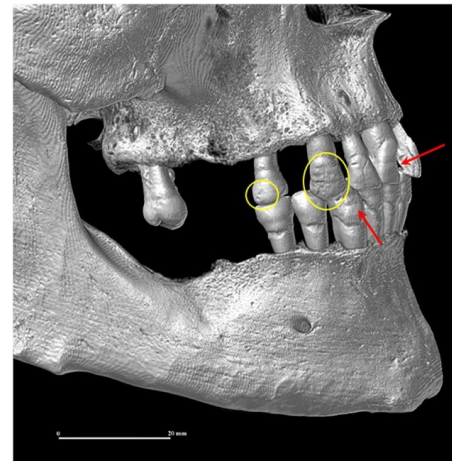
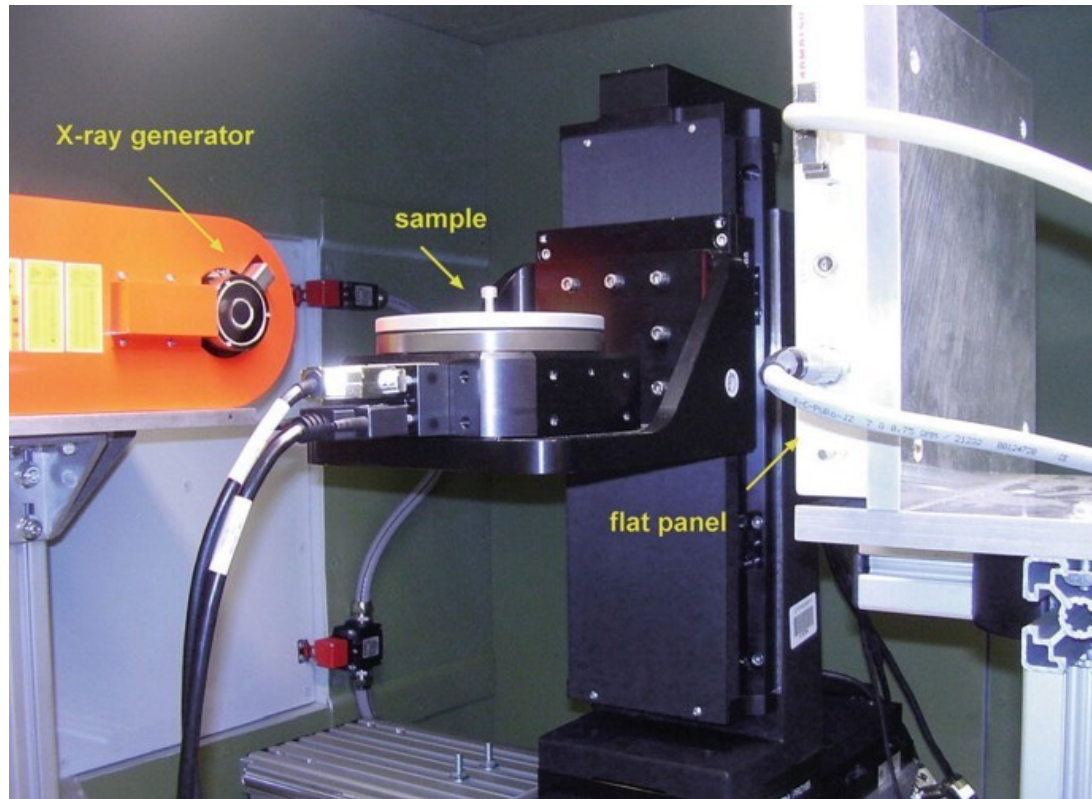


So what else?

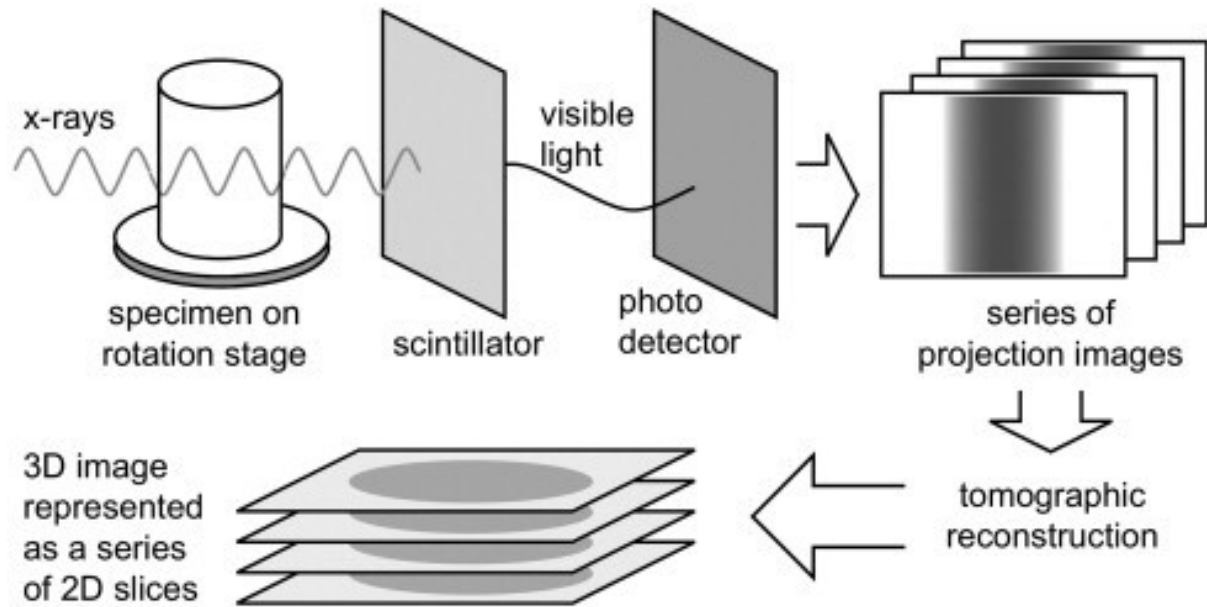
Micro-CT scanners



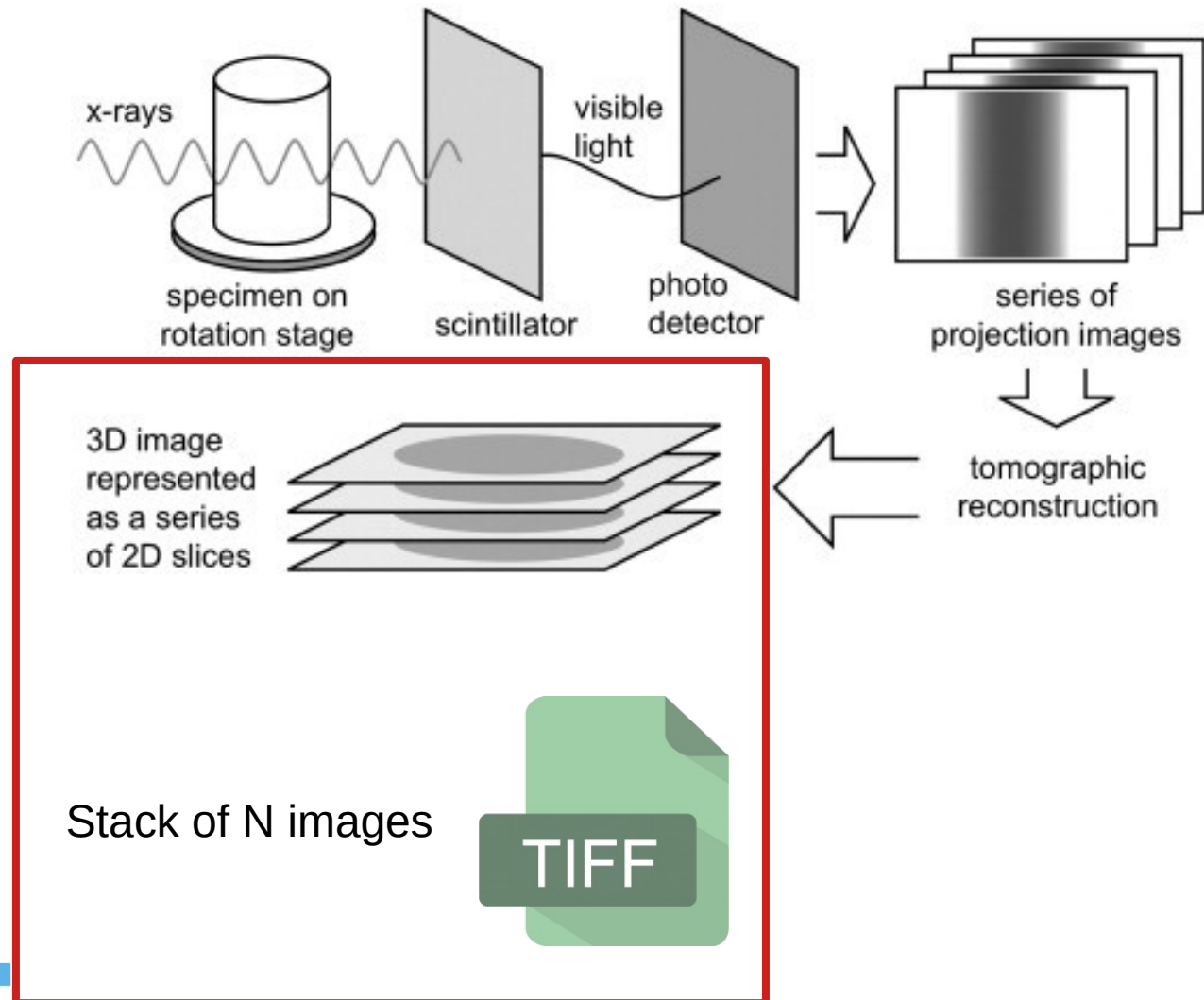
Micro-CT scanners



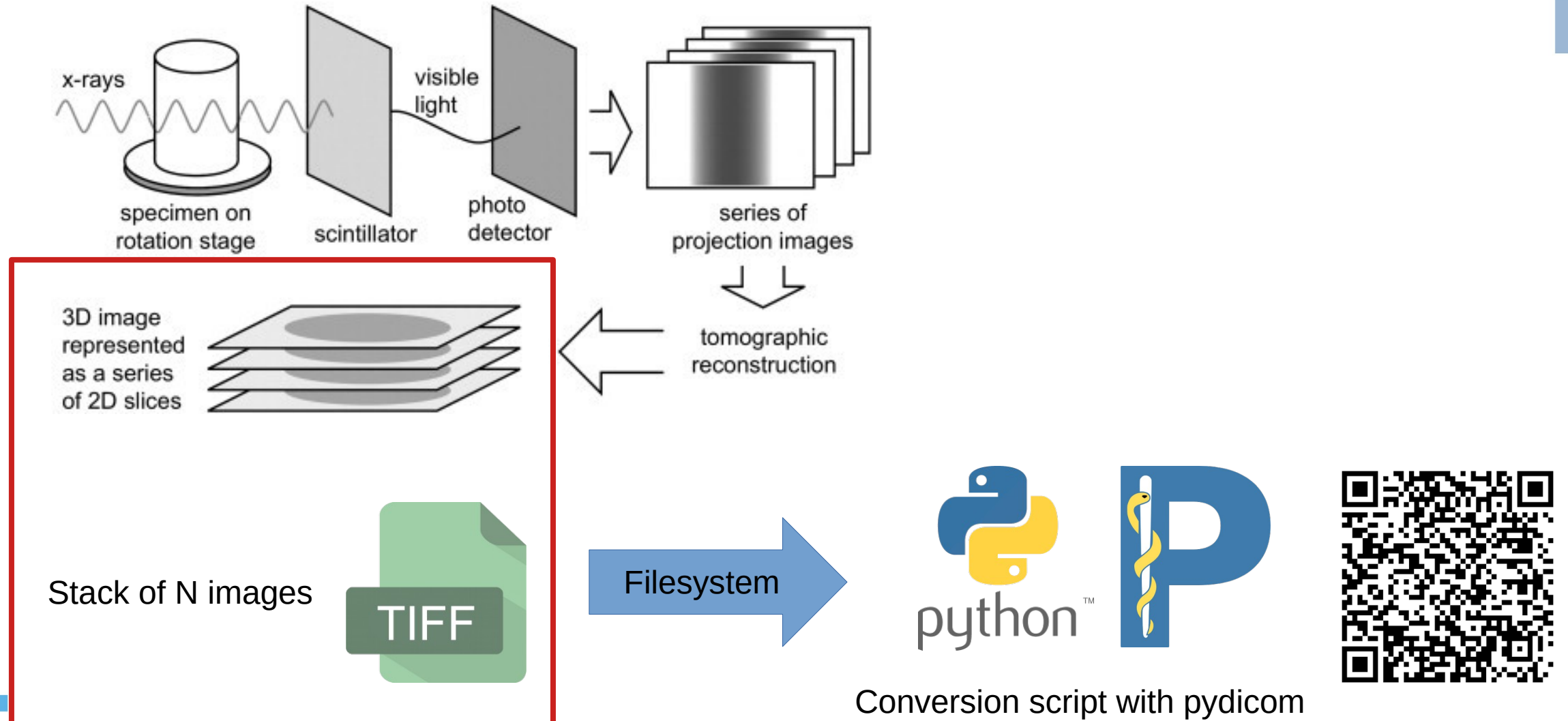
From micro-CT to DICOM



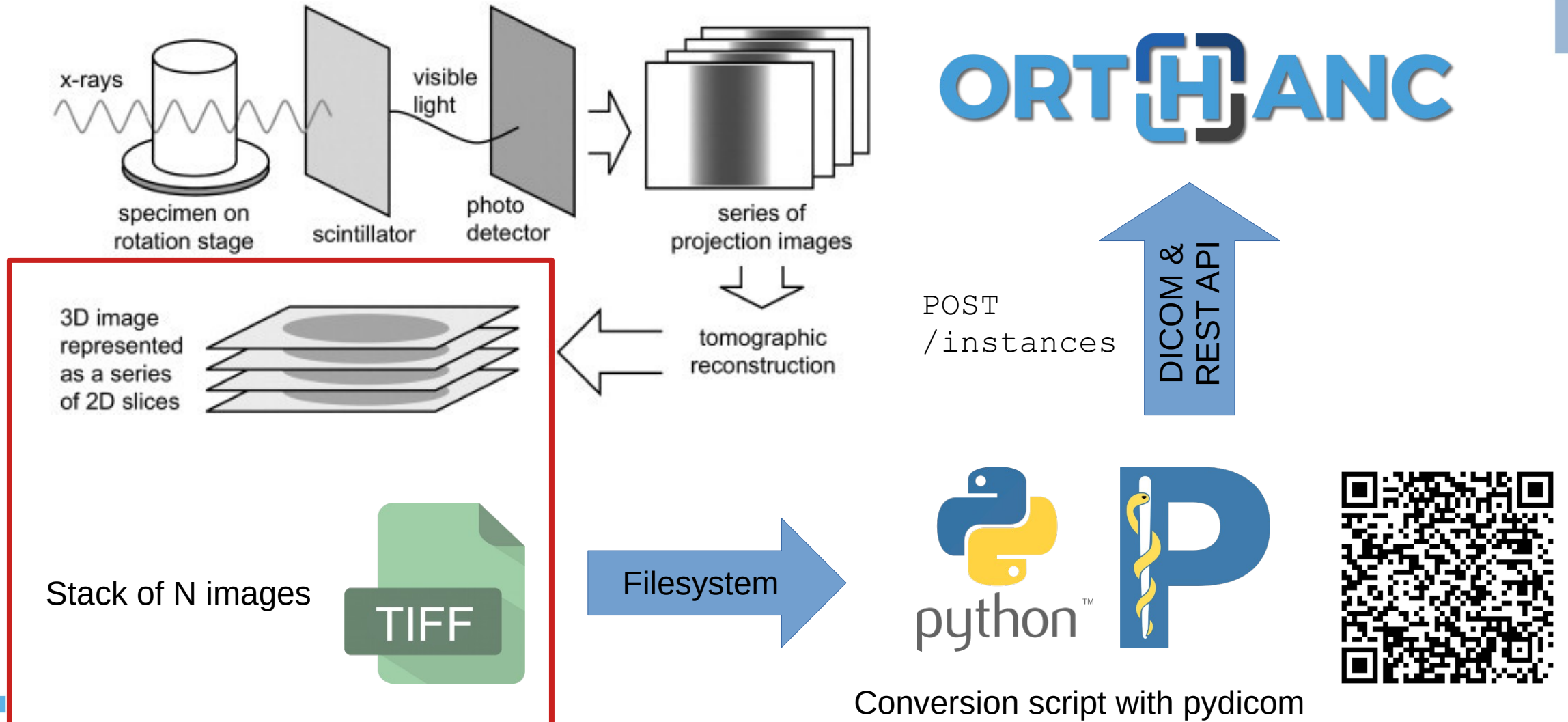
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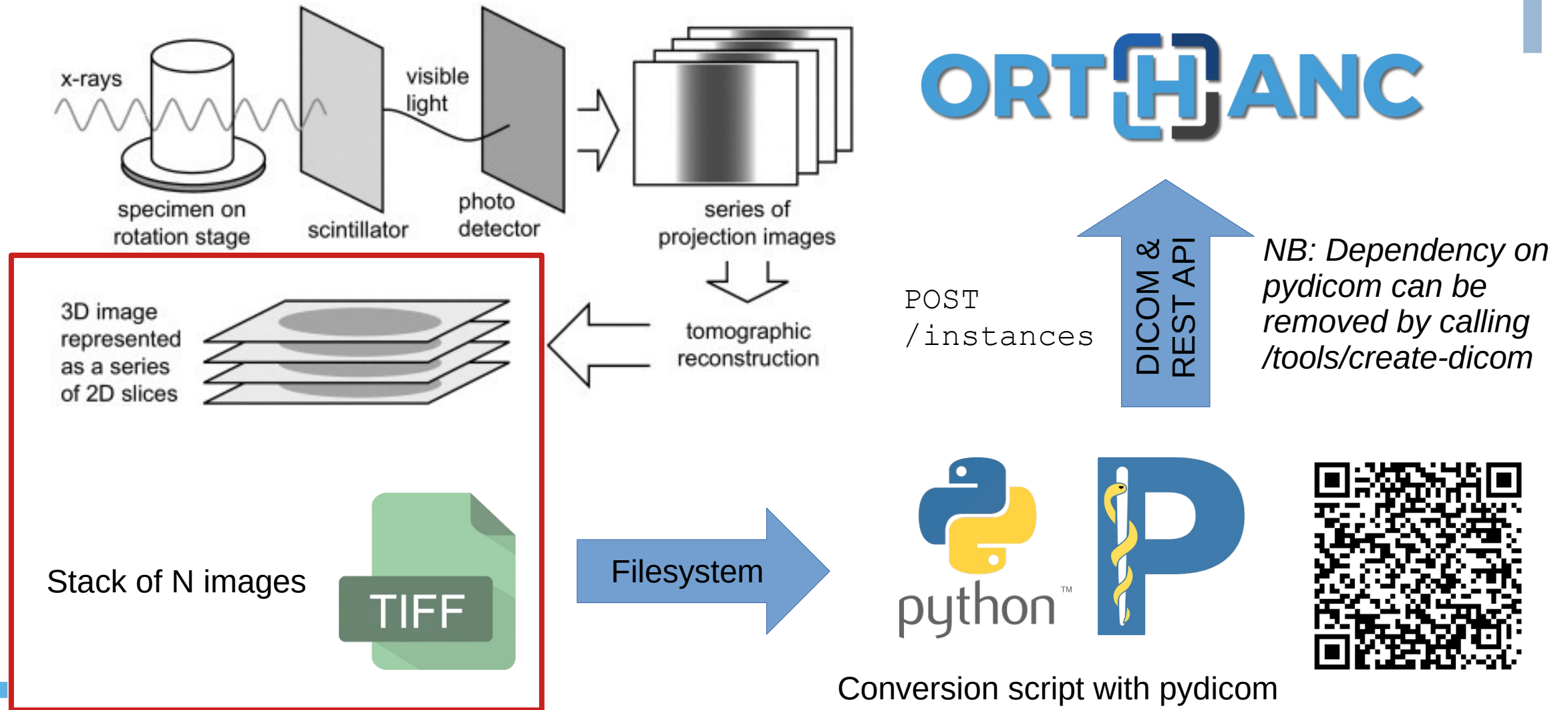
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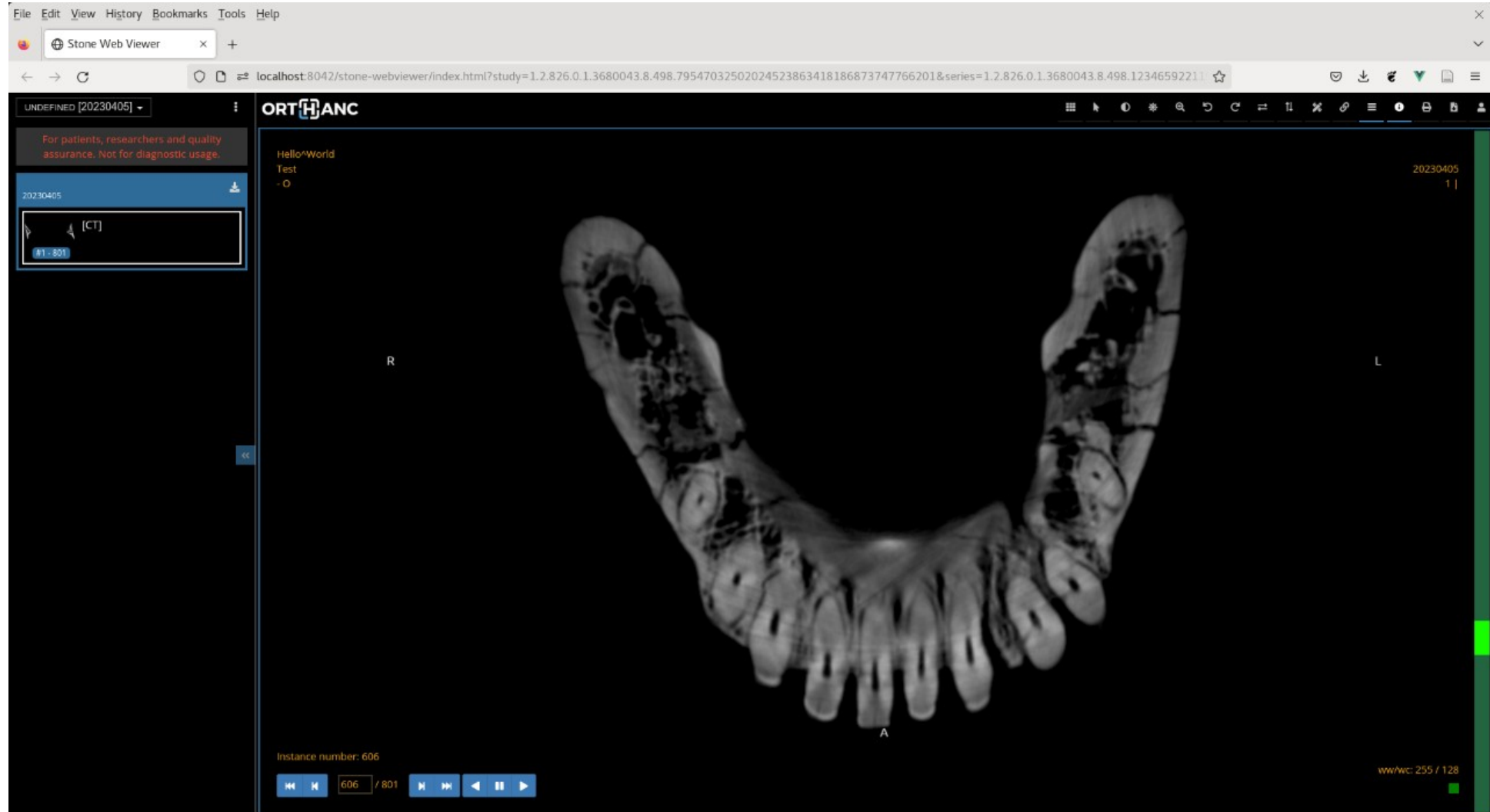
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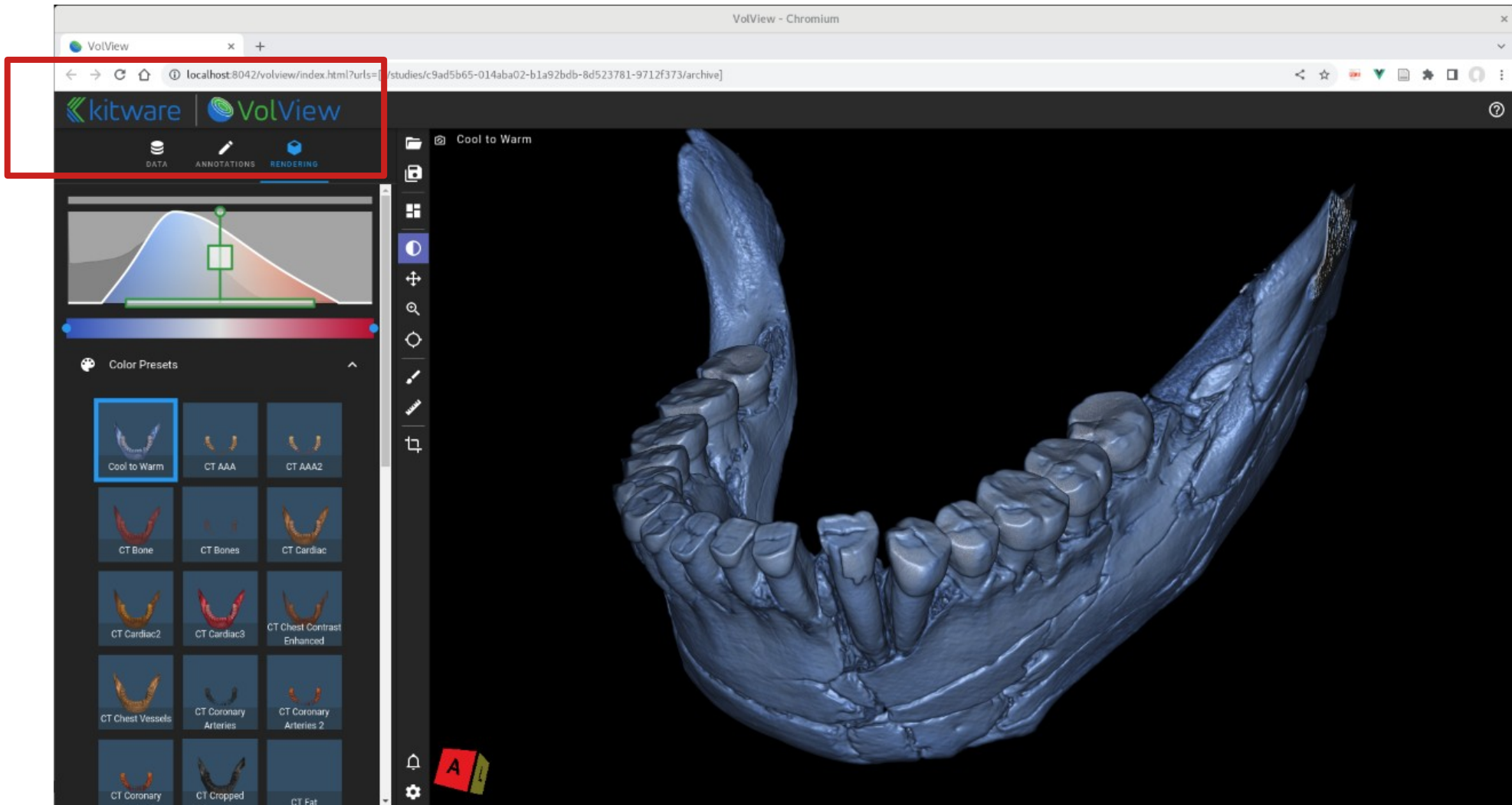
From micro-CT to DICOM



Teleradiology access using Stone Web viewer



Volumetric rendering using Kitware VolView



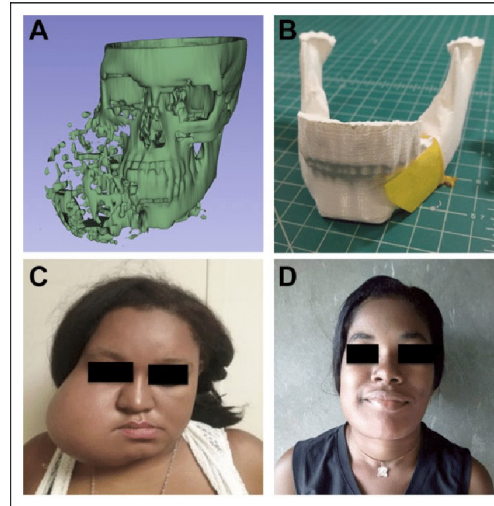
3D models

Some applications of 3D models

In medicine



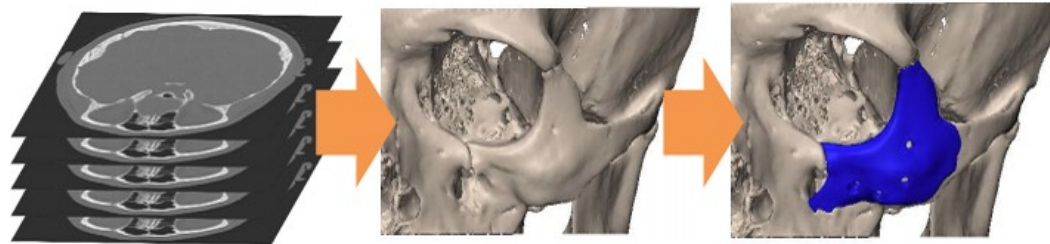
Training



Surgical planning



Patient education



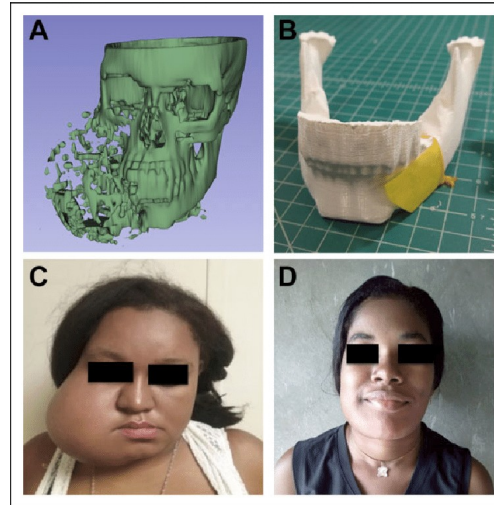
From CT-scan to 3D model to Patient Specific Implant design

Some applications of 3D models

In medicine



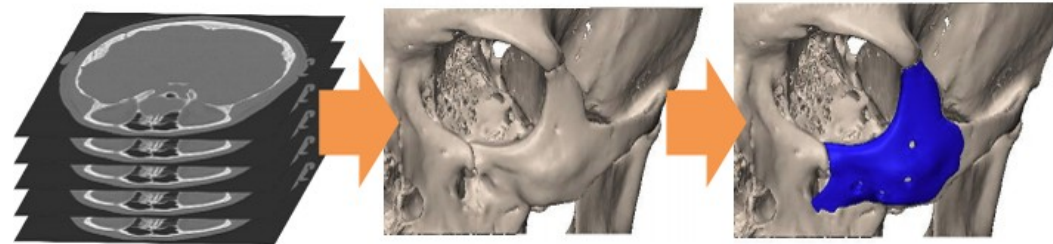
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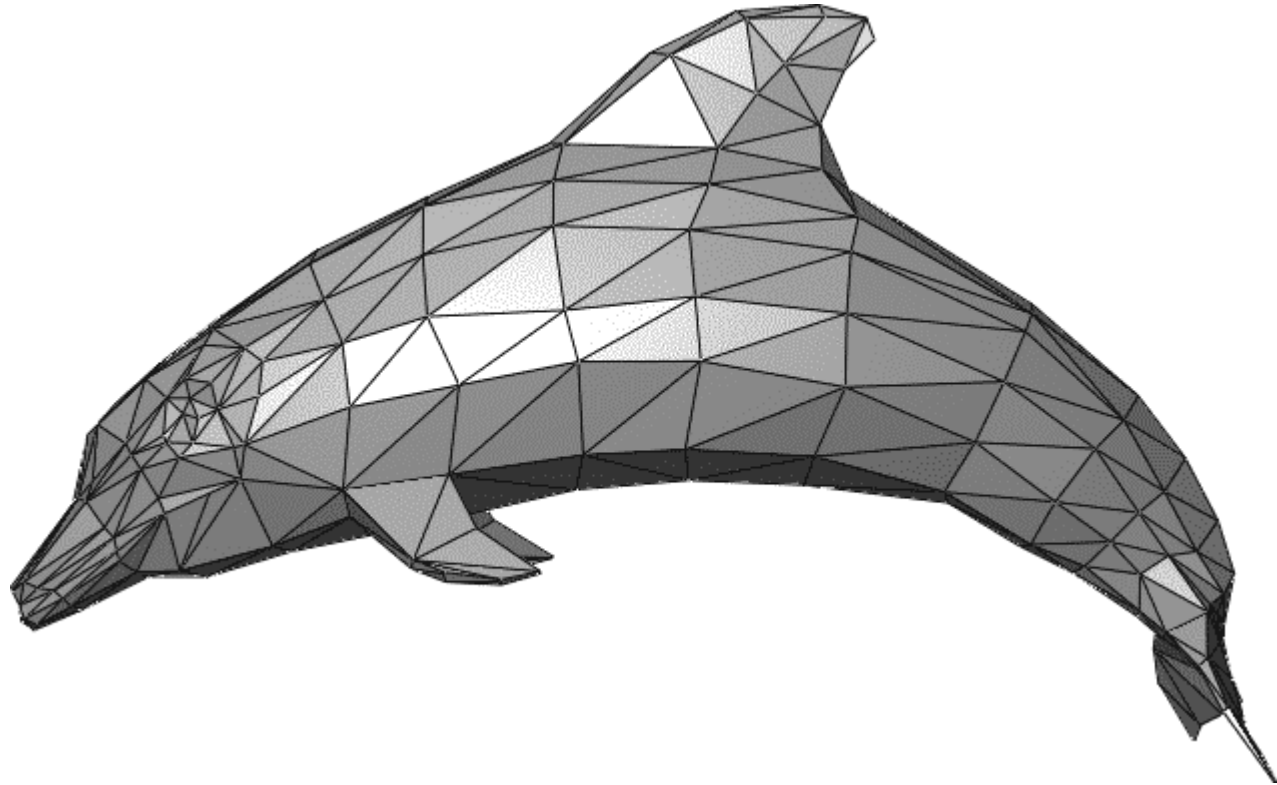


From CT-scan to 3D model to Patient Specific Implant design

For cultural heritage



STL file



- **Collection of small 3D triangle facets**
- Widely used for 3D printing
- OBJ file = add texture to STL
- STL and OBJ can be encapsulated inside DICOM, exactly like **PDF**



Encapsulation of STL into DICOM



Attribute Name	Tag	Type	Attribute Description
Measurement Units Code Sequence	(0040,08EA)	1	Units of distance for the coordinate system for the encapsulated 3D Manufacturing Model file. Only a single item shall be included in this Sequence.
->Include Table 8.8.1 "Code Sequence Macro Attributes" <u>DCIM 7063 "Model Scale Unit"</u>			
Model Modification	(0008,7001)	3	Specifies whether a modification of the observed anatomy (other than mirroring) was used to create the model (e.g. simulating an expected surgical result). In the negative, the model follows the observed patient anatomy in the source data. Enumerated Values: YES NO
Model Mirroring	(0008,7002)	3	Specifies whether mirroring of anatomy from the other side of the patient was used to create the model. Enumerated Values: YES NO
Model Usage Code Sequence	(0008,7003)	3	Specifies the use for which the manufactured object is intended. Only a single item shall be included in this Sequence.
->Include Table 8.8.1 "Code Sequence Macro Attributes" <u>DCIM 7064 "Model Usage"</u>			
Content Description	(0070,0081)	3	A description of the model.
Icon Image Sequence	(0008,0200)	3	A preview image representing the rendered model. Only a single item is permitted in this Sequence.
->Include Table C.7.1.1b "Image Pixel Macro Attributes" <u>See Section C.7.6.1.1.6 for further explanation</u>			
Derivation Algorithm Sequence	(0022,1612)	3	Software algorithm that created the 3D model. Only a single item shall be included in this Sequence.
->Include Table 10.19 "Algorithm Identification Macro Attributes"			
Model Group UID	(0008,7004)	3	Uniquely identifies a group to which the model belongs. Manufacturing models that share the same Model Group UID are considered distinct parts within the same assembly.
Recommended Display CIELab Value	(0062,0000)	3	Specifies the color recommended to be used for the model. This color applies both when digitally displaying the model and when selecting material for manufacturing. This would typically be used to visually distinguish between models that are part of the same assembly and/or provide best analog to real world appearance. The units are specified in PCS values, and the value is encoded as CIELab. This value may be superseded by individual colors that have been specified inside the encapsulated model (when the encapsulated format allows this). See Section C.10.7.1.1
Recommended Presentation Opacity	(0066,000C)	3	Specifies the opacity recommended to be used for the model. This opacity applies both when digitally displaying the model and when selecting material for manufacturing. A non-opaque value would typically be specified when either (a) another model grouped in the same assembly needs to be visible behind or inside this model, or (b) the model represents anatomy that is not fully opaque. If not present, then it is assumed the model should be presented and manufactured as opaque. See Section C.27.1.1.3

Standardized DICOM tags

Challenges

BUT

- Few tools to encapsulate STL as a DICOM file
- Is it possible to automatically segment a CT-scan or a micro-CT?
- No support for viewing STL in most PACS
- Lack of free implementations



Challenges

BUT

This is implemented in the REST API
since **Orthanc 1.12.1!**

POST
`/tools/create-dicom`

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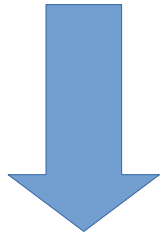
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This is the goal of the
new **orthanc-stl plugin!**

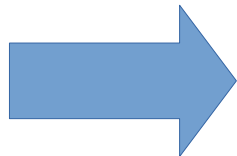
(Option 1) From binary NifTI to DICOM STL

- NifTI is a simple file format for 3D volumes, initially targeted at neuroimaging
- **Orthanc can convert DICOM series into NifTI** (this is the orthanc-neuro plugin)
- **TotalSegmentator** is a free, command-line tool for organ segmentation using deep learning

DICOM CT



NifTI



RSNA TotalSegmentator: Robust Segmentation of 104 Anatomic Structures in CT Images

Key Result

The proposed model provides automatic, robust and publicly available segmentations of major anatomical structures in CT images.

Patients:

- **Training dataset:** 1204 CT examinations randomly sampled from routine clinical studies

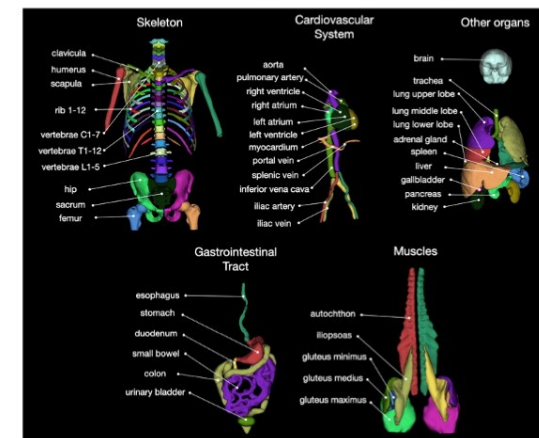
Methods:

- 104 anatomical structures (27 organs, 59 bones, 10 muscles, 8 vessels) were segmented on CT images in the training dataset.
- An nnU-Net segmentation algorithm was trained on the dataset, and performance was evaluated.

Results:

- The model achieved a Dice score of 0.943 (95% CI: 0.938, 0.947) on the test set.
- The model outperformed another publicly available segmentation model on a subset of the test set: Dice score, 0.932 vs. 0.871

Overview of structures segmented by TotalSegmentator:

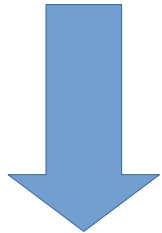


NifTI

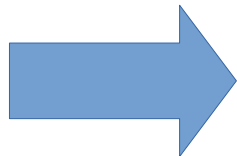
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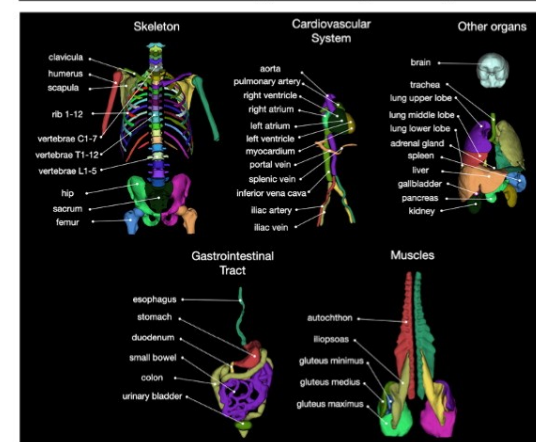
Methods:

- 104 anatomical structures (27 organs, 59 bones, 10 muscles, 8 vessels) were segmented on CT images in the training dataset.
- An nnU-Net segmentation algorithm was trained on the dataset, and performance was evaluated.

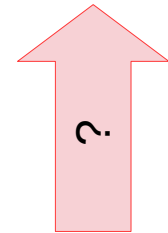
Results:

- The model achieved a Dice score of 0.943 (95% CI: 0.938, 0.947) on the test set.
- The model outperformed another publicly available segmentation model on a subset of the test set: Dice score, 0.932 vs. 0.871

Overview of structures segmented by TotalSegmentator:



DICOM STL

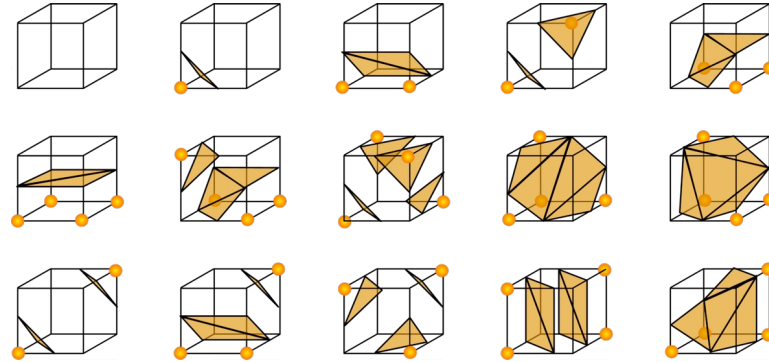


NifTI

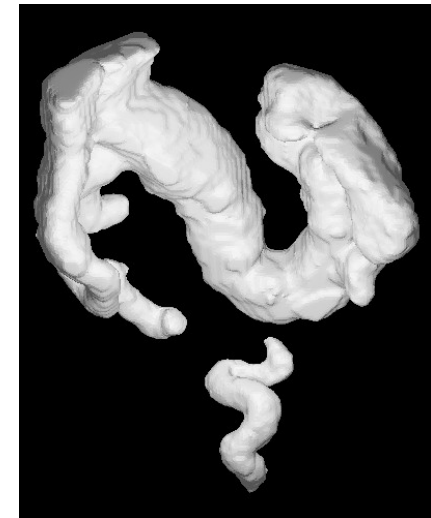
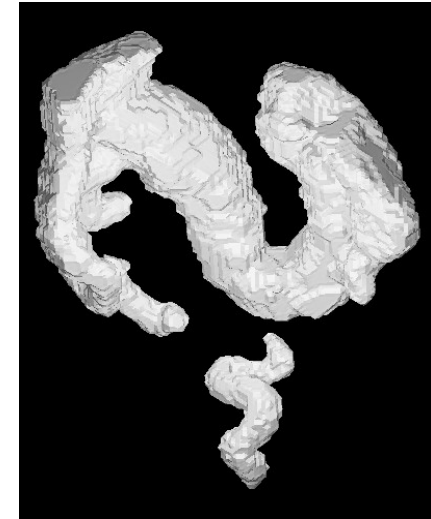
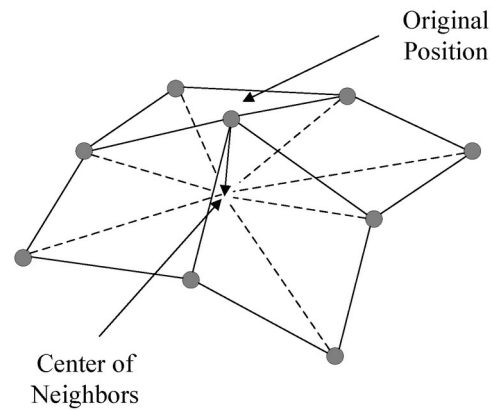


From 3D binary image to STL

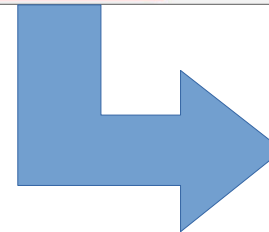
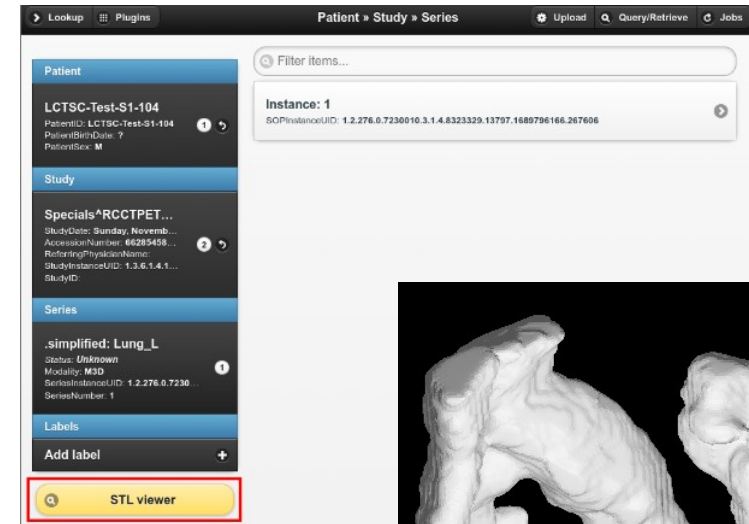
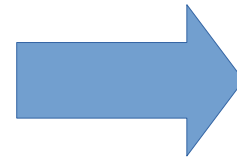
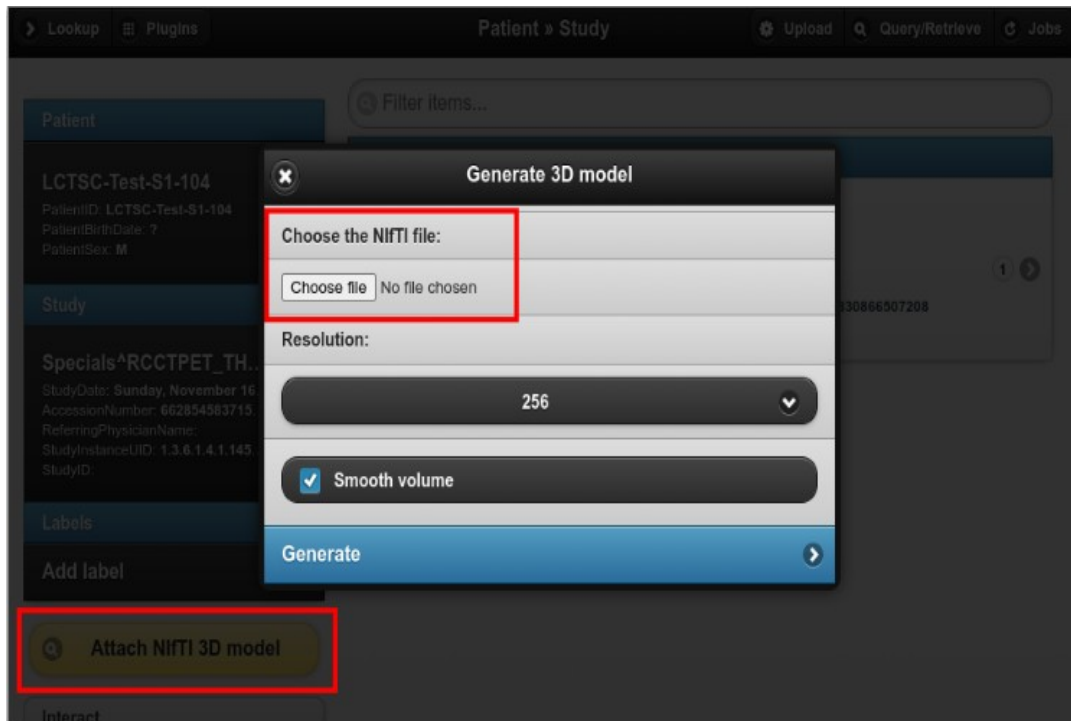
(1) Marching Cubes algorithm



(2) Laplacian smoothing

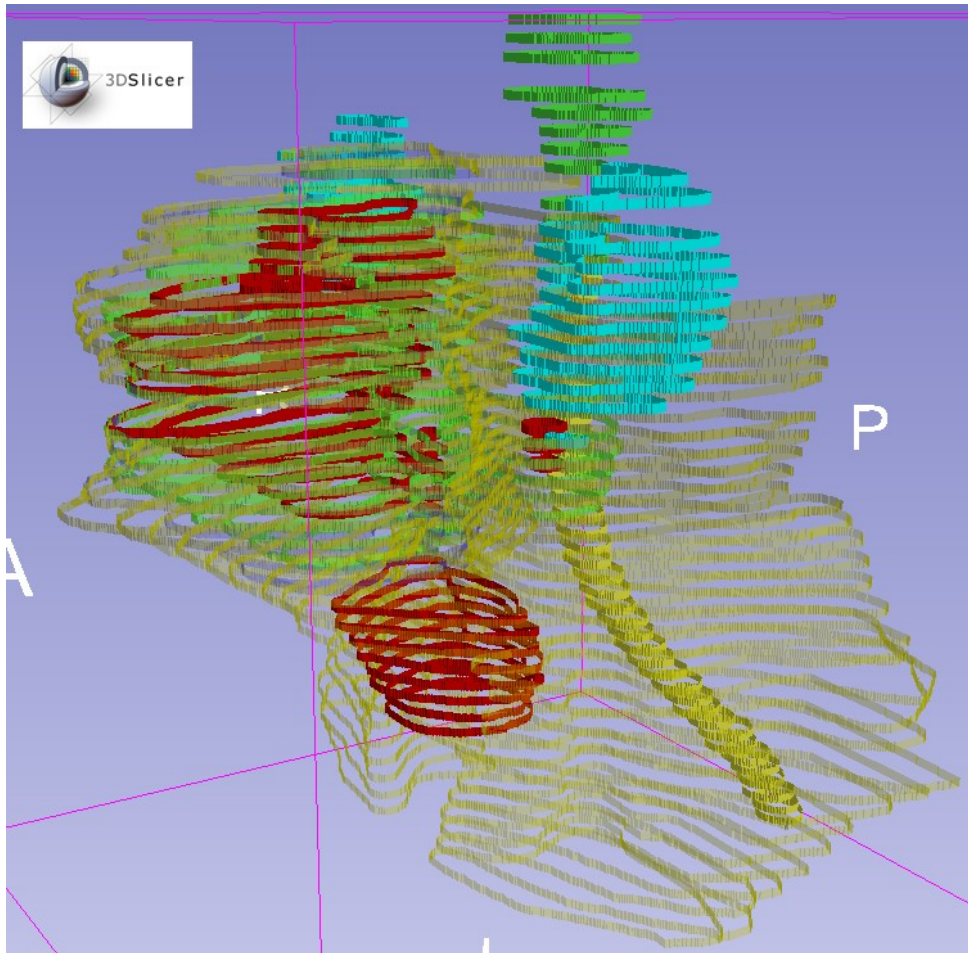


Orthanc plugin: Create STL from NIfTI



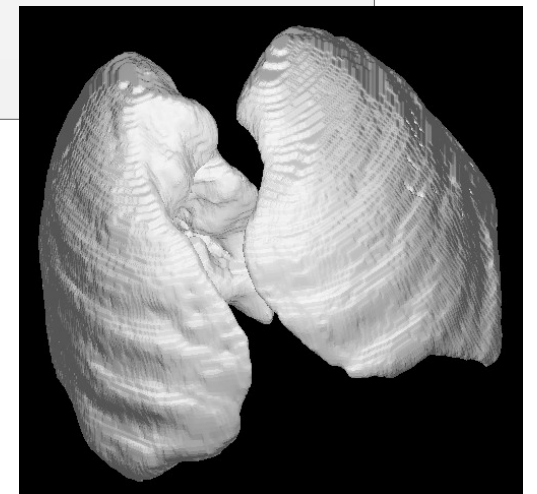
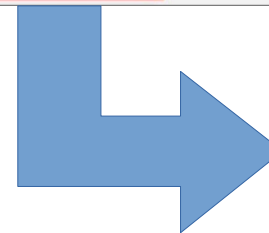
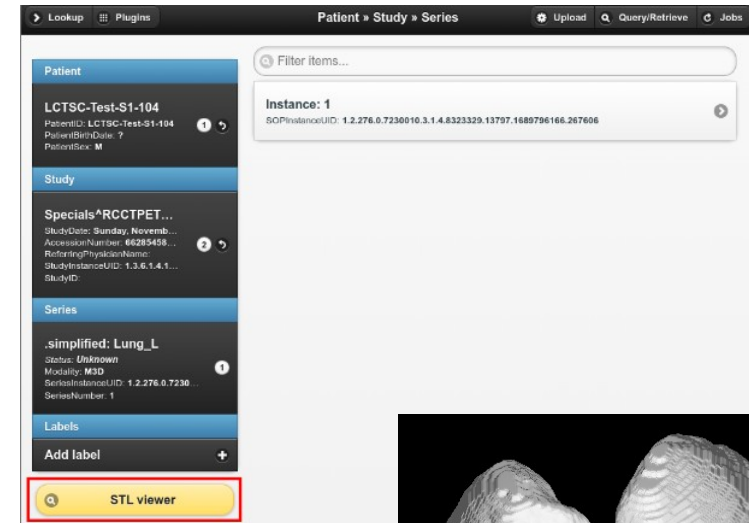
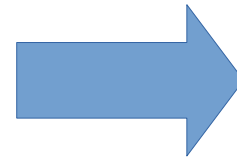
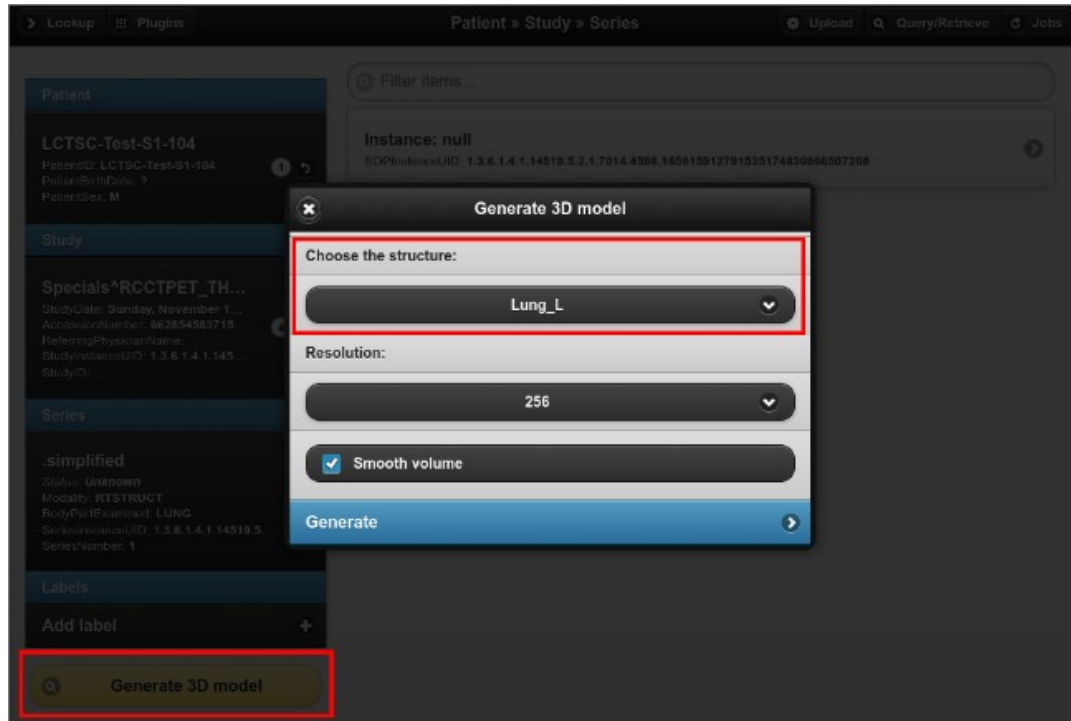
VTK + `POST /tools/create-dicom`

(Option 2) From DICOM RT-STRUCT to DICOM STL



- In radiotherapy, physicians manually delineate the **organs-at-risk**
- This results in **DICOM RT-STRUCT** files, that encode a set of polygons in 3D
- It is possible to **fill a 3D binary bitmap** using these polygons, then also apply Marching Cubes

Orthanc plugin: Create STL from DICOM RT-STRUCT

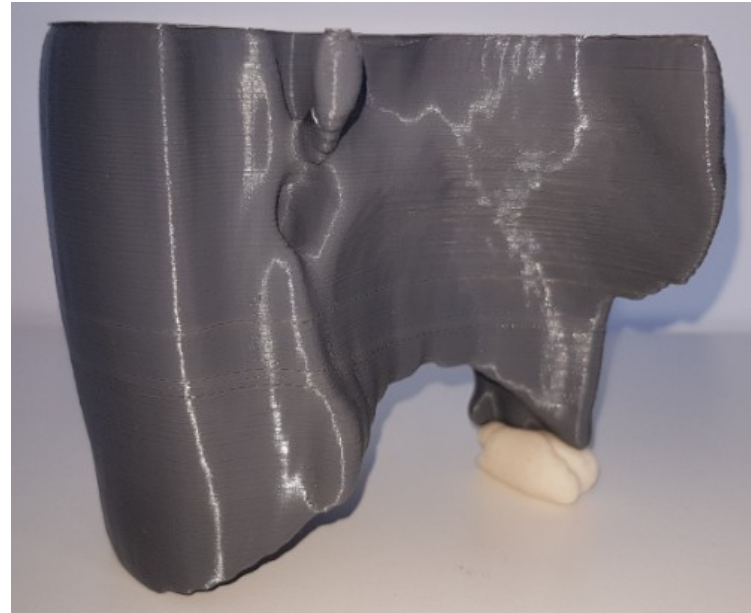
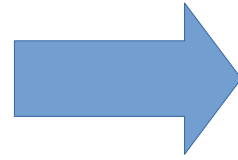
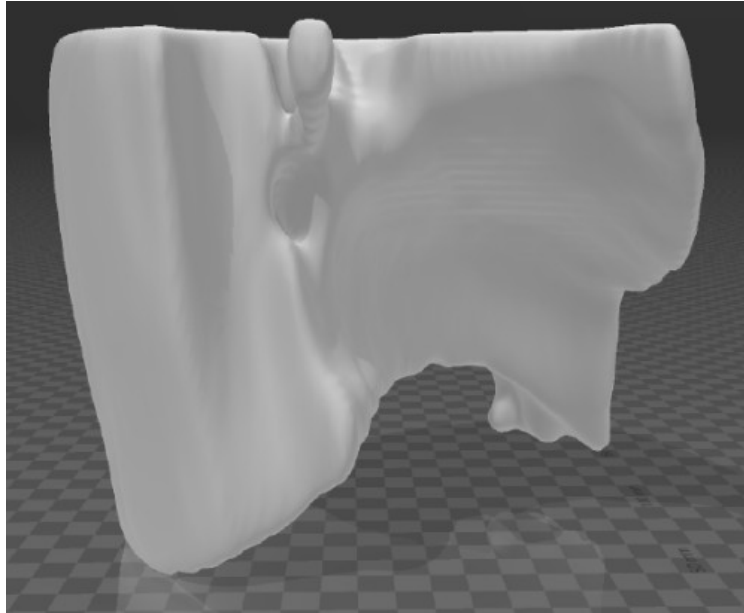


VTK + `POST /tools/create-dicom`

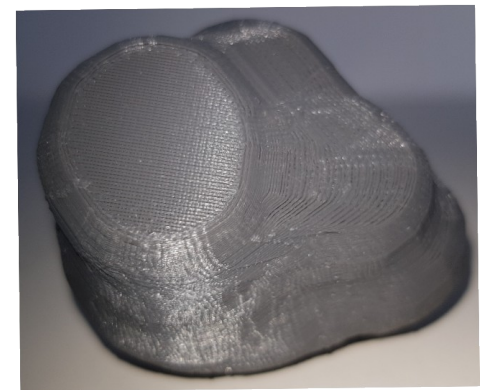
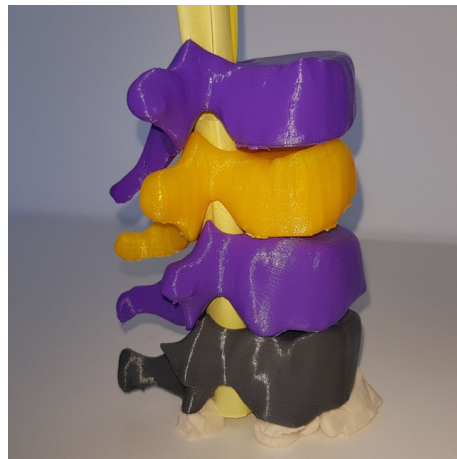
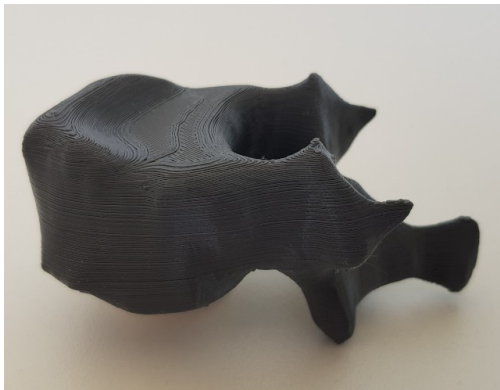
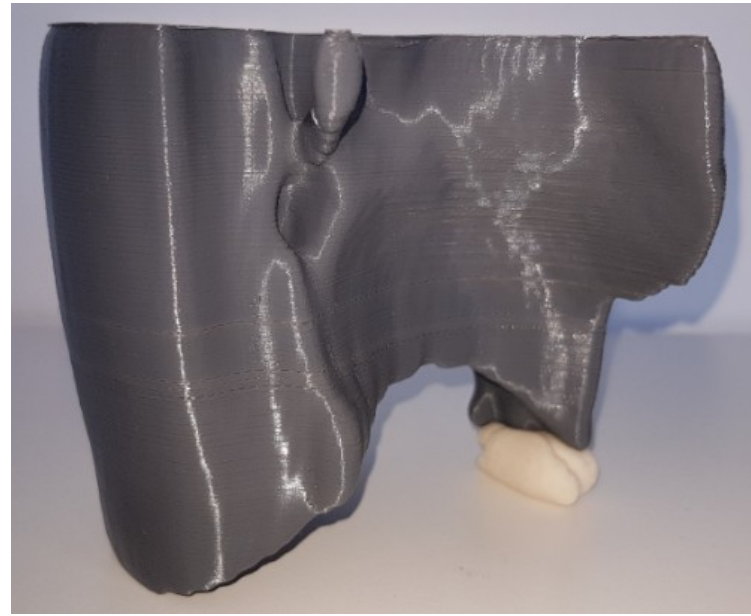
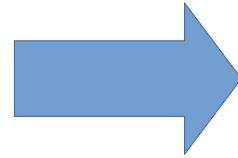
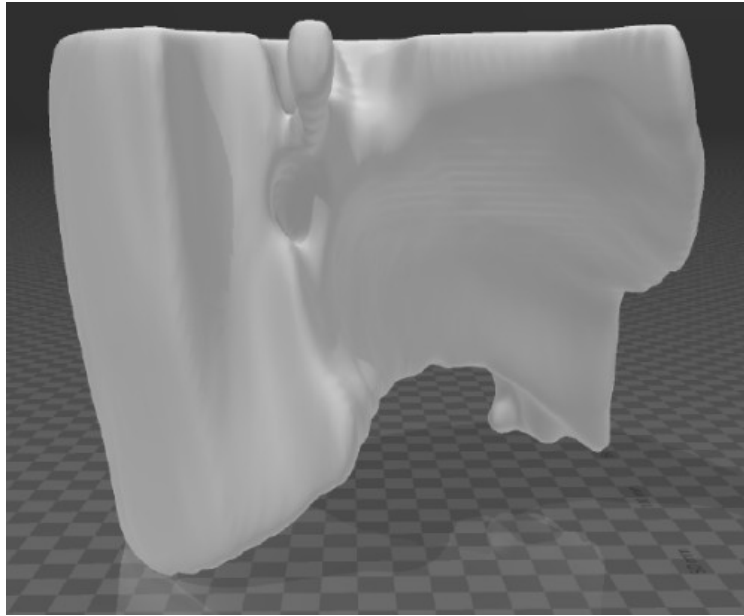
Next possible step: 3D-printing!



Next possible step: 3D-printing!



Next possible step: 3D-printing!



IIIF

IIF

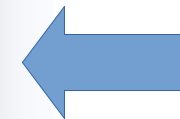
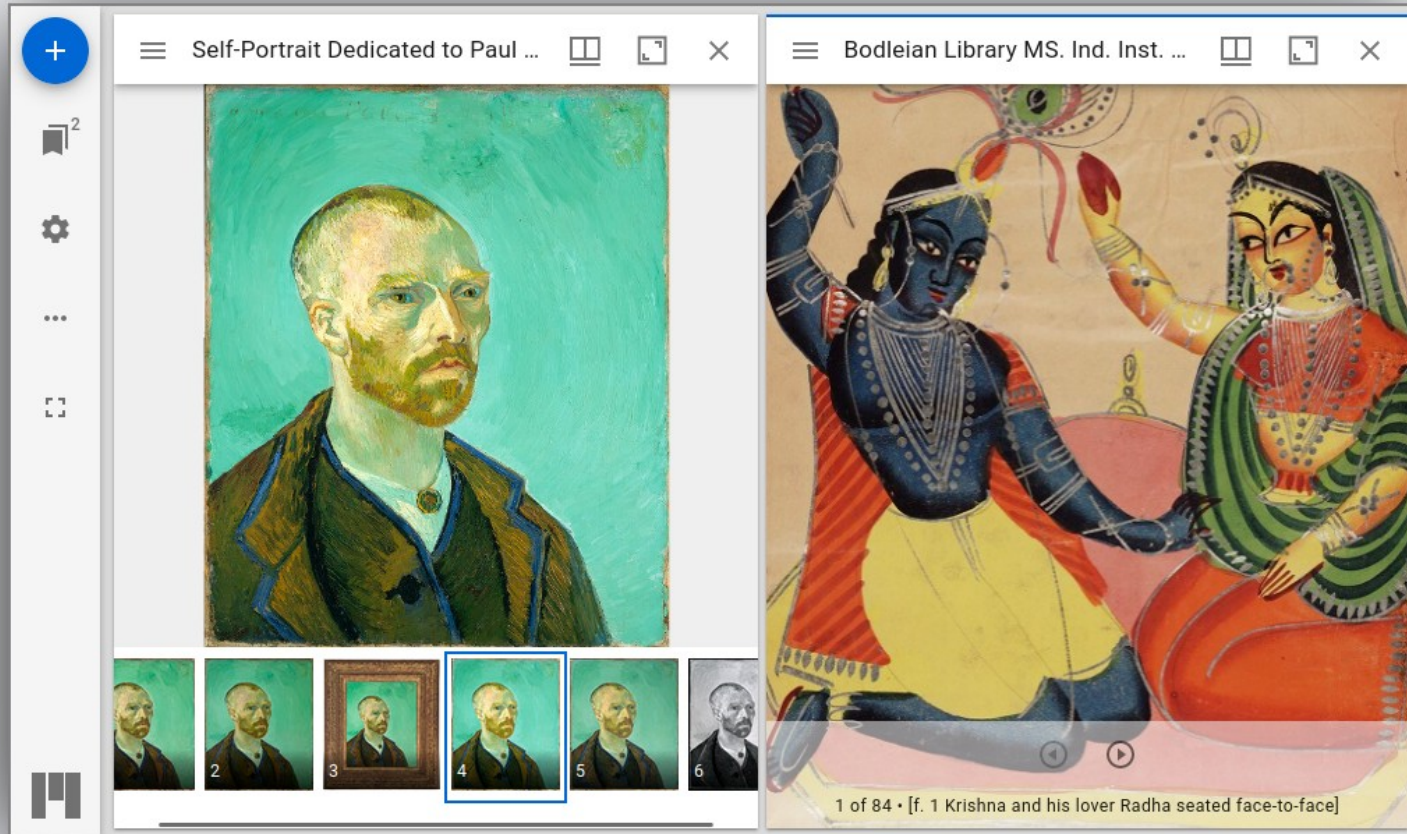
- Huge number of collections of 2D images **all around the world**, and stored in different software
- In the context of cultural heritage, those images come with a **high resolution**
- How to provide a **consistent, efficient access over Internet** to all those resources?



International
Image
Interoperability
Framework



Example of IIF presentation layer with Mirador

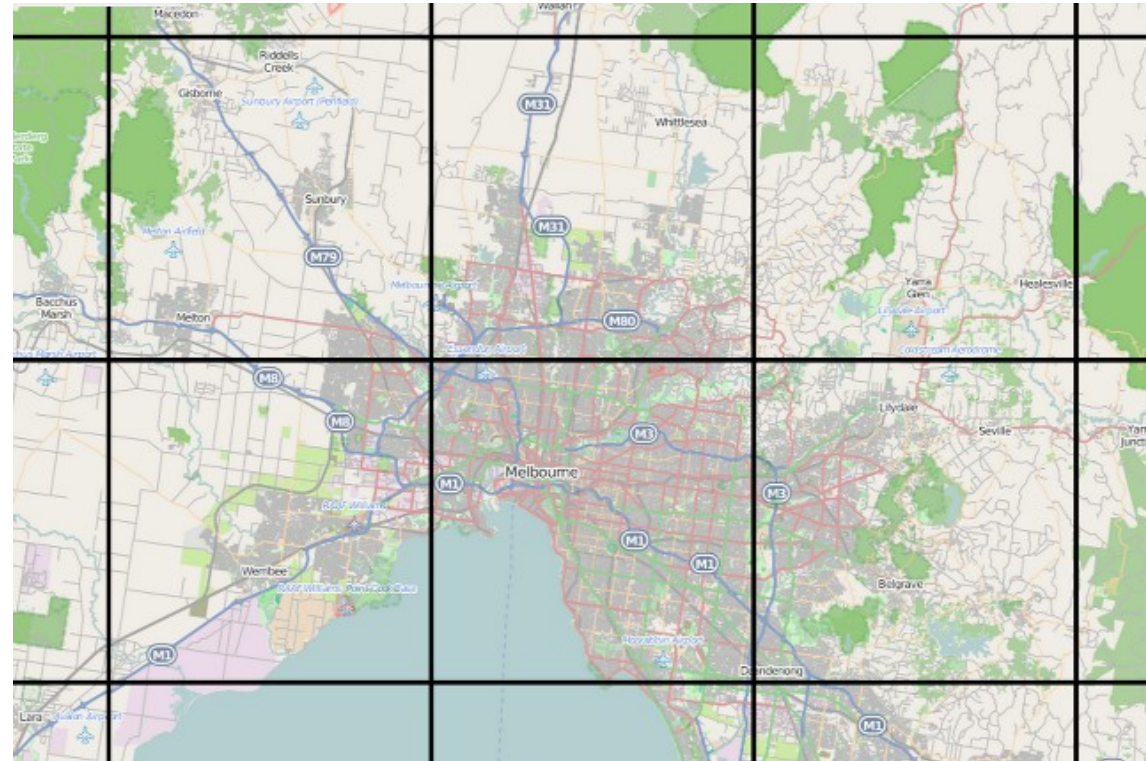


Images possibly come from different servers

<https://projectmirador.org/>

Behind the scenes: Manifest + Server of image tiles

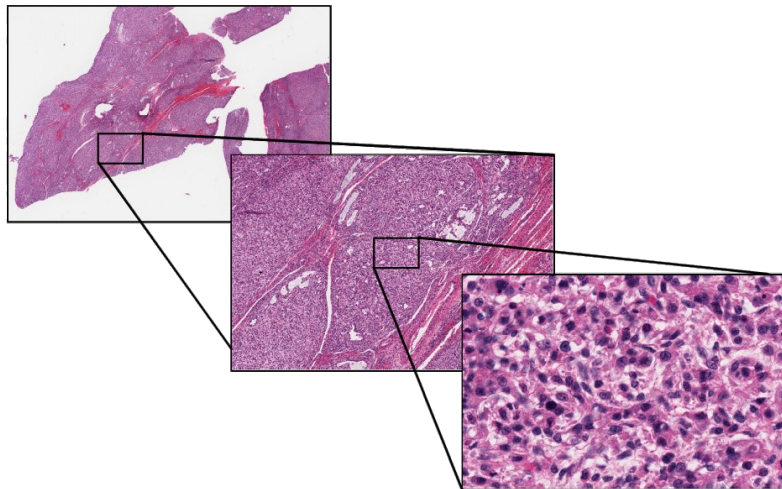
```
{
  "@context": "http://iiif.io/api/presentation/3/context.json",
  "id": "https://wsi.orthanc-server.com/orthanc/wsi/iiif/series/6",
  "items": [
    {
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      "id": "https://wsi.orthanc-server.com/orthanc/wsi/iiif/64",
      "items": [
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          "items": [
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                "height": 30016,
                "id": "https://wsi.orthanc-server.com/orth",
                "service": [
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                    "id": "https://wsi.orthanc-server.co",
                    "profile": "level0",
                    "type": "ImageService3"
                  }
                ],
                "type": "Image",
                "width": 43136
              },
              "id": "https://wsi.orthanc-server.com/orthanc",
              "motivation": "painting",
              "target": "https://wsi.orthanc-server.com/ort",
              "type": "Annotation"
            }
          ],
          "type": "AnnotationPage"
        },
        {
          "label": {
            "en": [ "" ]
          },
          "type": "Canvas",
          "width": 43136
        }
      ],
      "label": {
        "en": [ "20170120 - SM - - " ]
      },
      "type": "Manifest"
    }
  ]
}
```



Serves selected portions of the image on-the-fly

Describes the parameters of the image

Direct link with WSI plugin for digital pathology in Orthanc!



Direct link with WSI plugin for digital pathology in Orthanc!

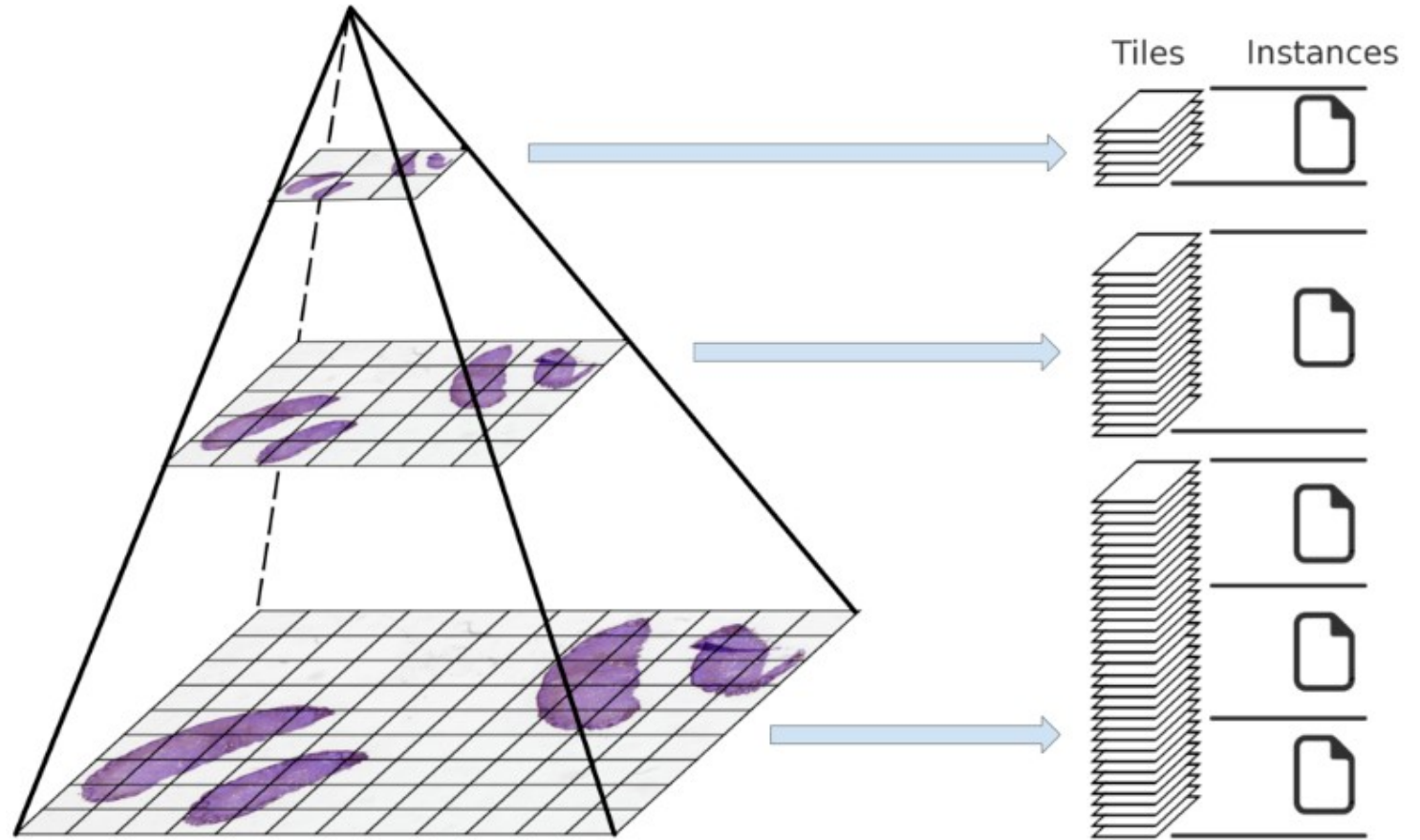
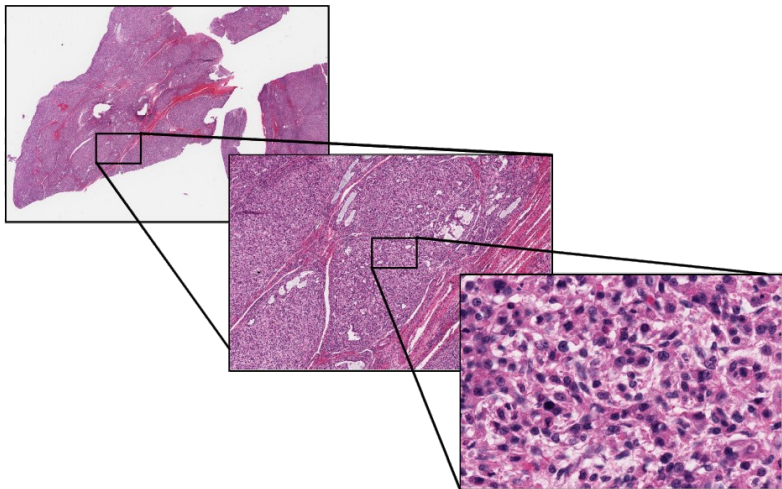
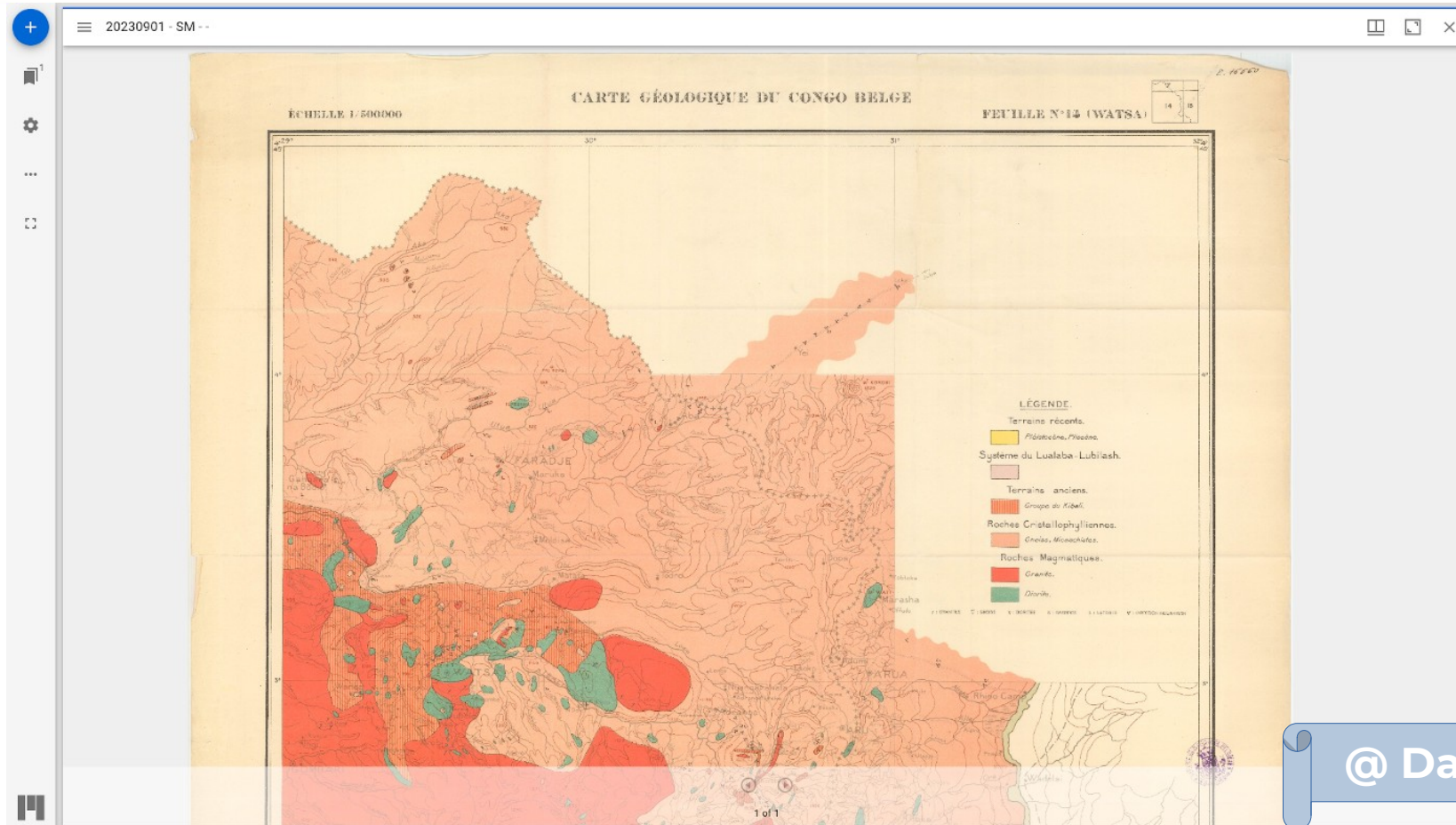


Figure 1: Mapping a multi-resolution pyramid according to the DICOM standard (DICOM Standards Committee, Working Group 26, Pathology, 2010). Each level of the pyramid is a downscaled version of the whole-slide image, and is decomposed as a set of tiles. The tiles are encoded as separate frames of multi-frame DICOM instances (files).

WSI plugin now also publishes IIF manifests

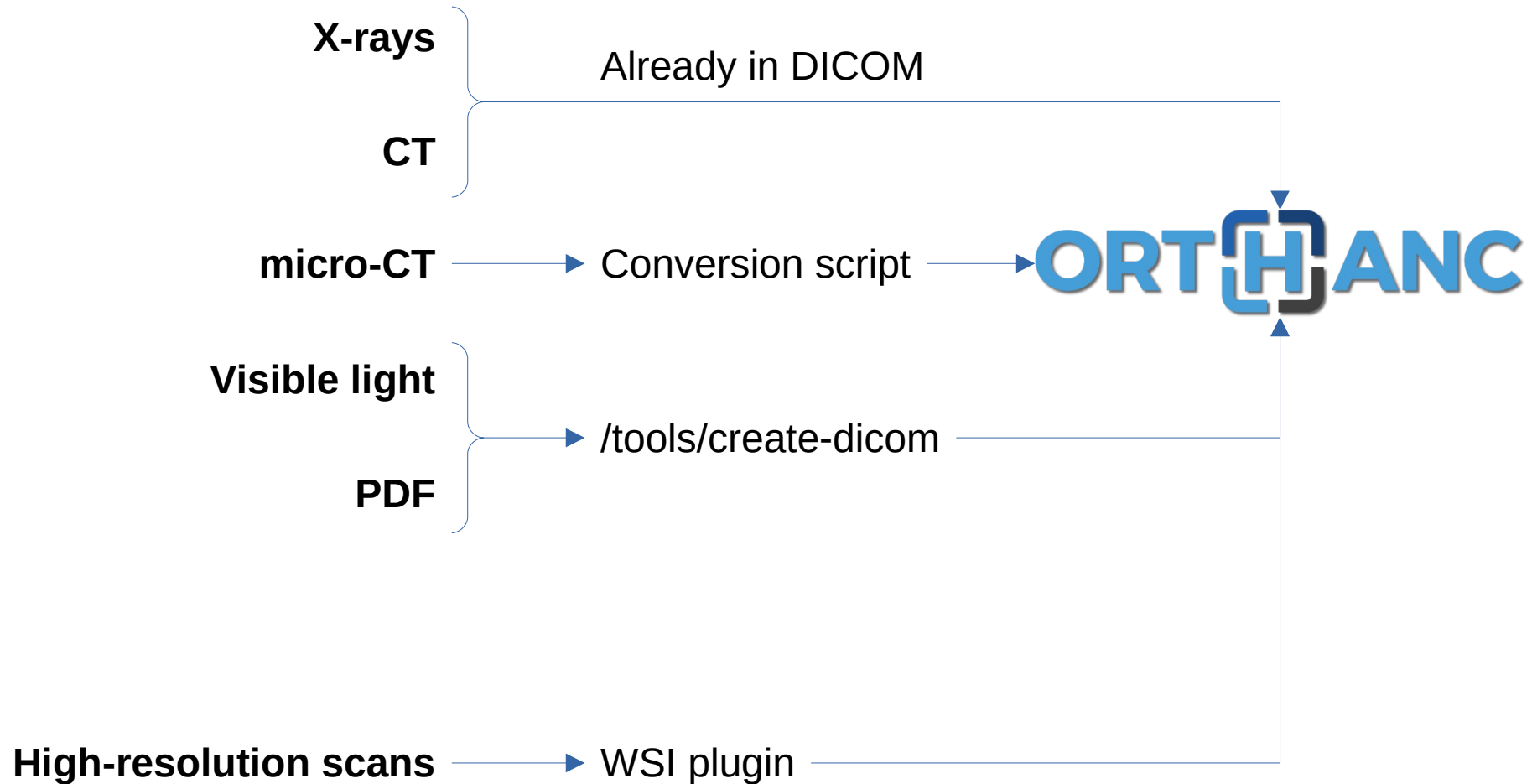


DICOM can be used as a storage layer below the IIF presentation layer!

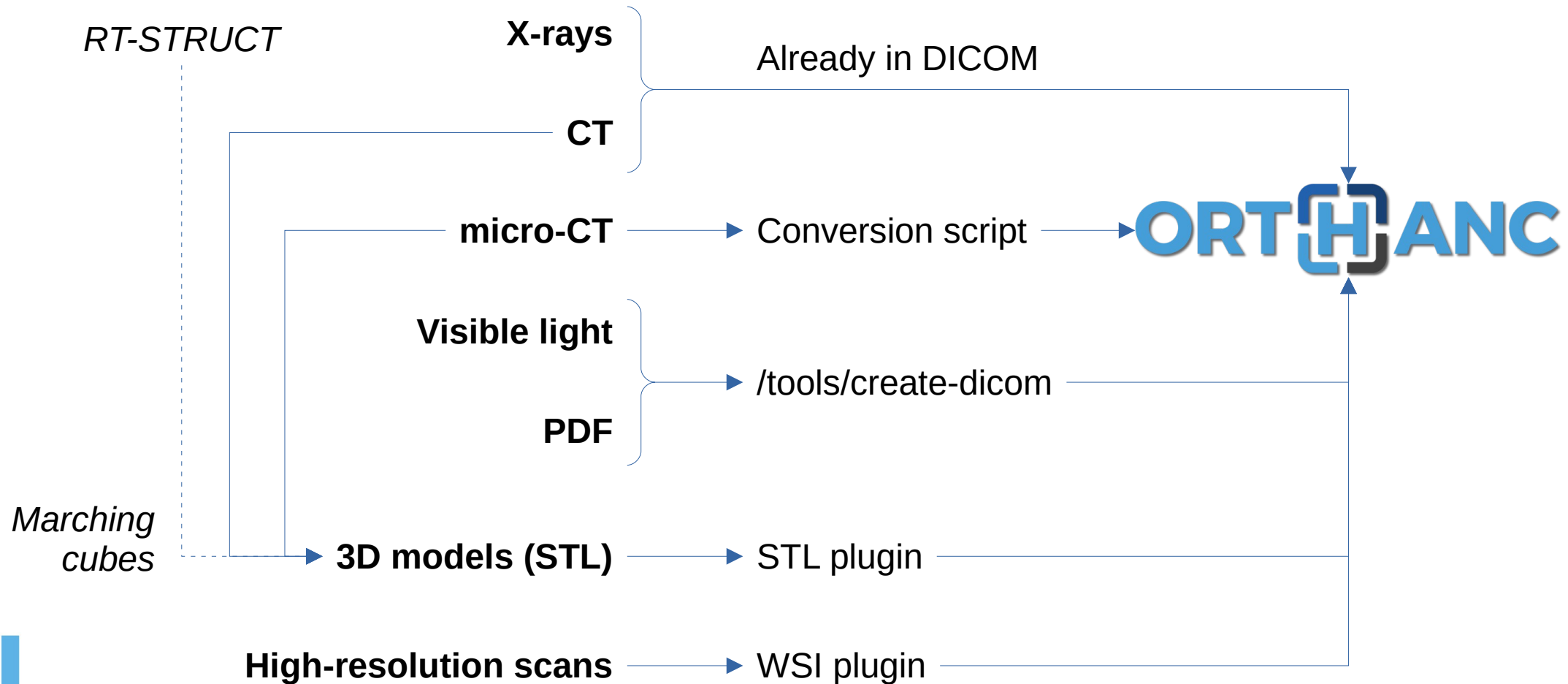
Opportunity for long-term preservation of high-resolution images using Orthanc

Conclusions

DICOM as the universal format for cultural heritage?

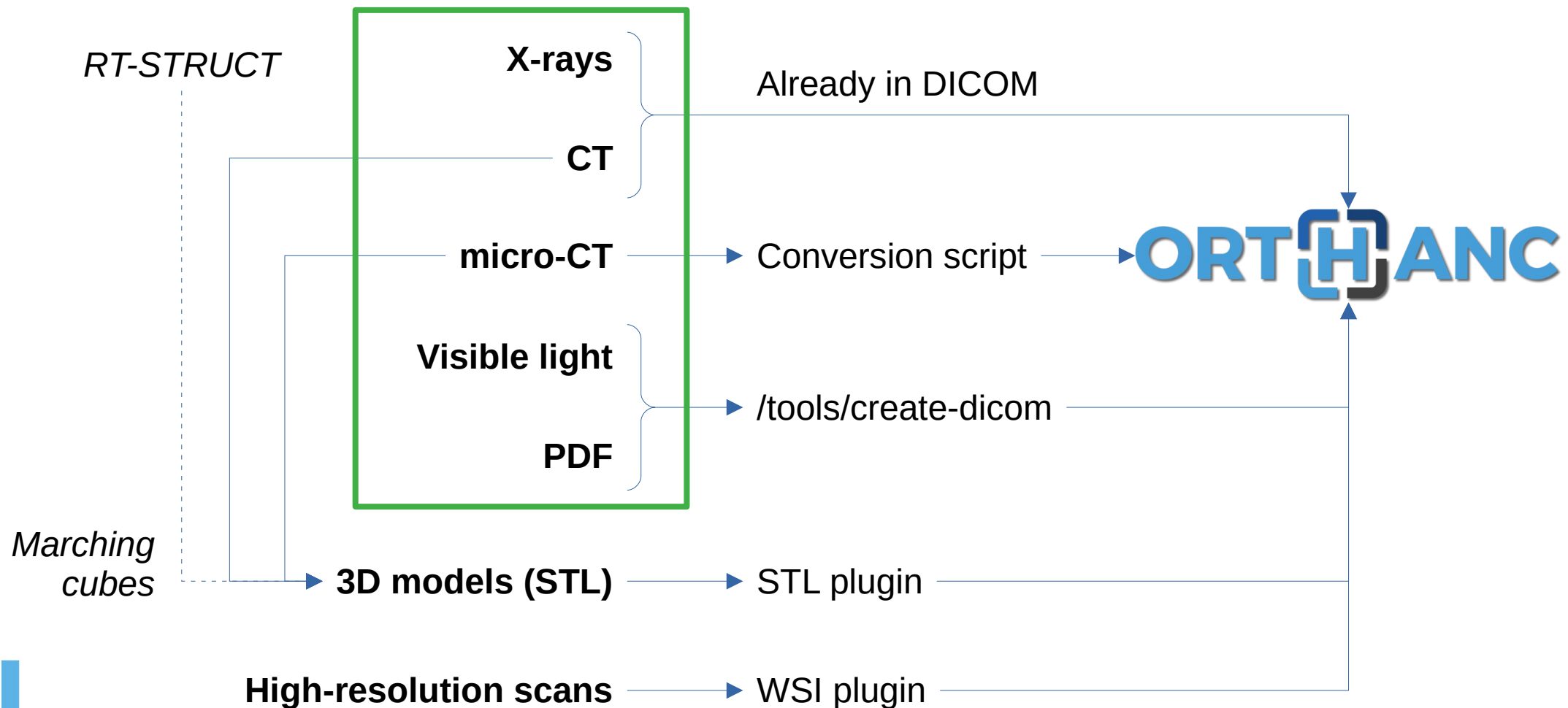


DICOM as the universal format for cultural heritage?



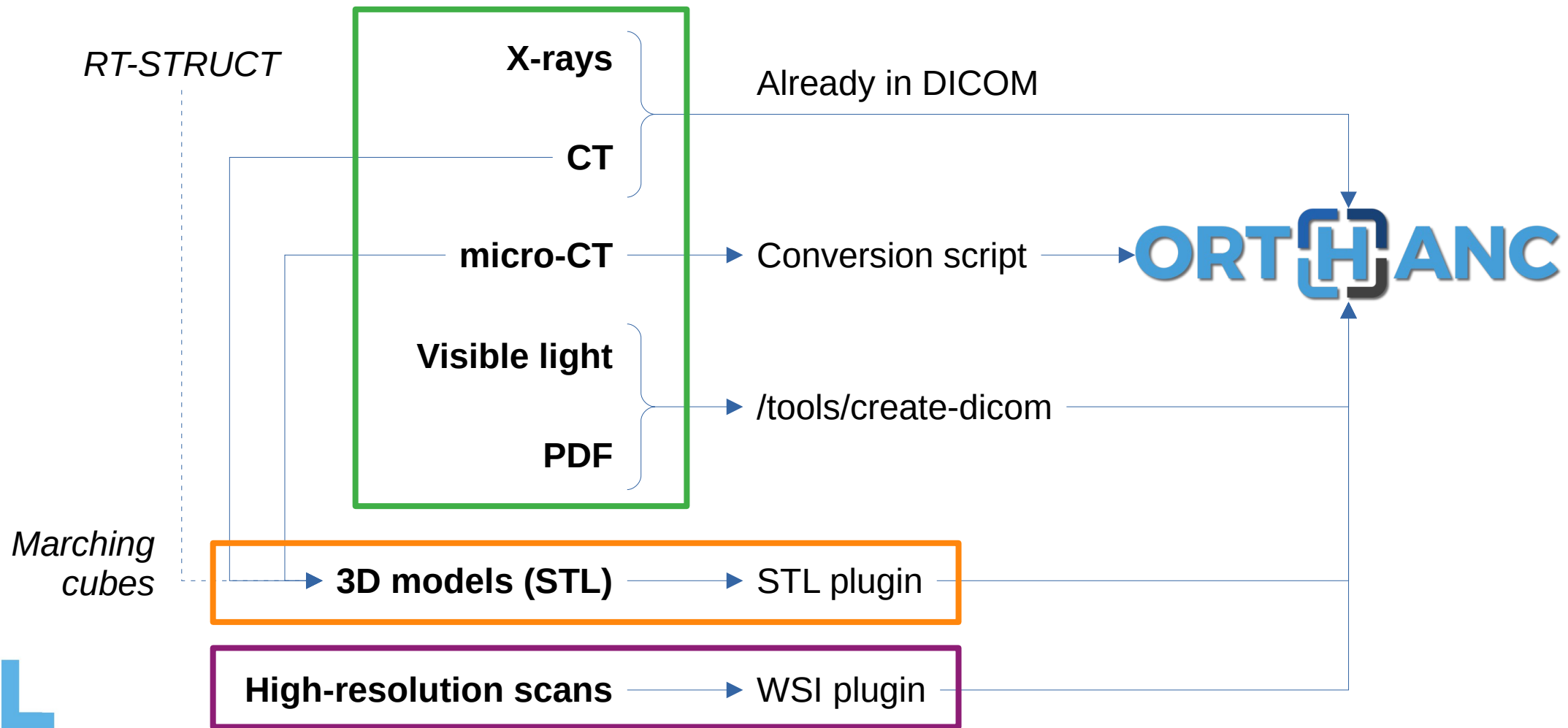
DICOM as the universal format for cultural heritage?

Stone Web viewer / OHIF / Kitware VolView



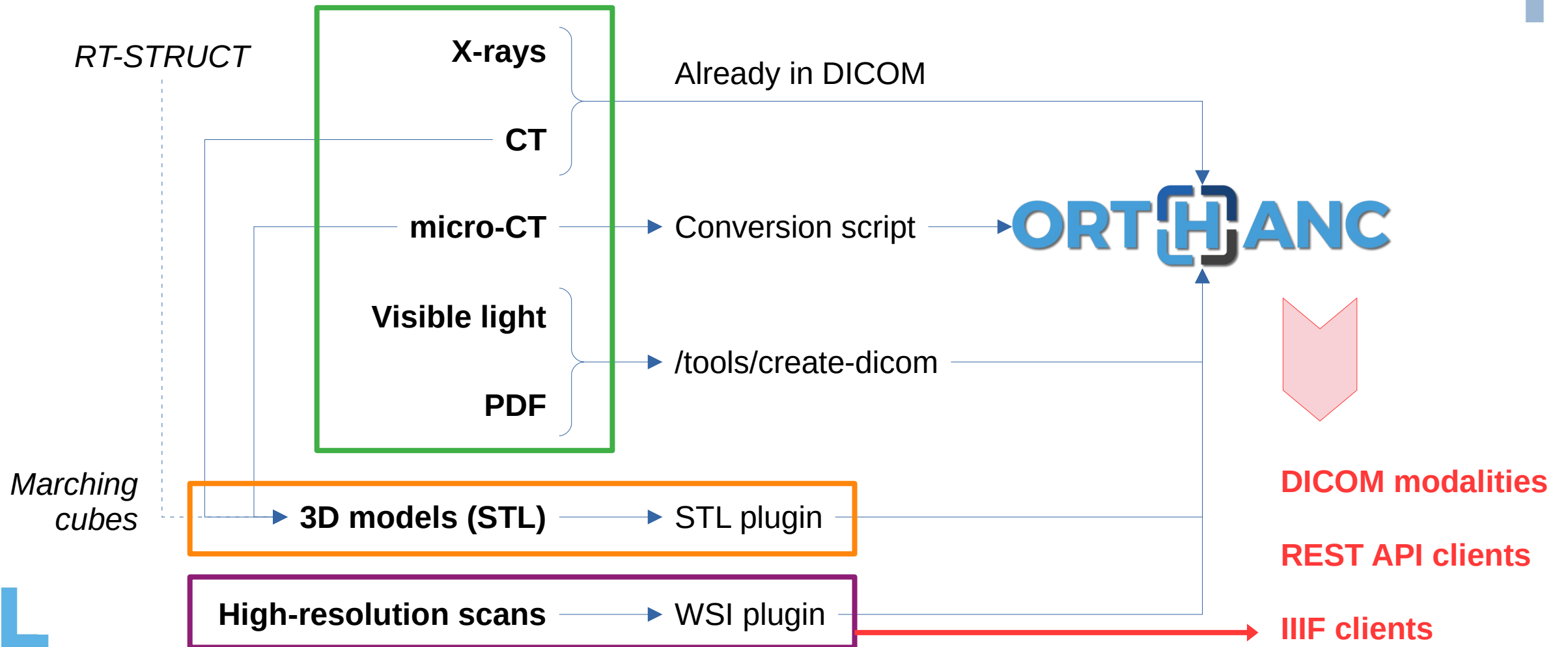
DICOM as the universal format for cultural heritage?

Stone Web viewer / OHIF / Kitware VolView



DICOM as the universal format for cultural heritage?

Stone Web viewer / OHIF / Kitware VolView



Work in progress

- Integrate **waveforms**, e.g. for bats and aquatic animals (cf. DICOM WG-32: Neurophysiology Data)
- Integrate **textured 3D models** (cf. DICOM “Encapsulated OBJ Information Object Definition”)
- Integrate **progressive loading of large 3D models** (encapsulate Nexus files as private tags)
- Integrate **better viewer** (i.e. Online 3D Viewer)
- Integrate **deep learning segmentation** inside the STL plugin
- Deploy a prototype for selected collections in one museum

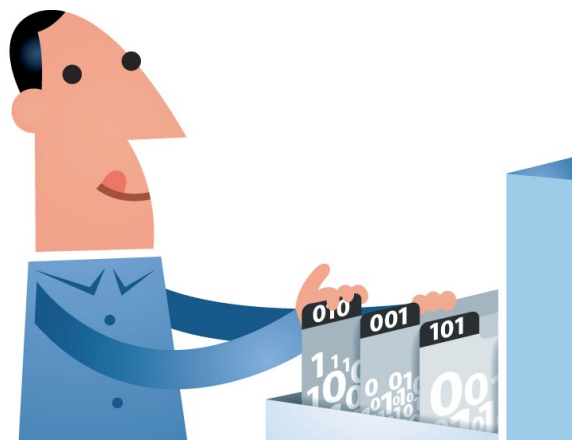


Our mission statement

ORT^HANC

“Freely share knowledge about medical imaging”

...which is also important for cultural heritage!



Digital
Public
Goods
Alliance



Side note: How to support Orthanc?



- **Financial donations**
- Buy **professional support**
- **Contact:** Alain Mazy & Benoît Crickboom

NB: A list of local-level freelancers is also available in the Orthanc Book!

<https://book.orthanc-server.com/users/support.html>



- **Cite** the reference papers [Jodogne, 2018]
- Propose working on a **joint publication**
- Include as a partner in an **international research project** (e.g., COST, EU H2020...)
- **Contact:** Sébastien Jodogne



UCLouvain