Orthanc — Lightweight, RESTful DICOM Server for Healthcare and Medical Research

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What is Radiotherapy?

"The medical use of ionizing radiation, generally as part of cancer treatment, to control or kill malignant cells."

At CHU of Liège (Belgium)

- $\approx$ 2400 new cases per year.
- First radiotherapy department in Wallonia.
- Second in Belgium (KUL).

Modern Treatment Machines at Liège

Elekta

- Linear accelerator ($\approx$ 20MV).
- Embedded imaging for positioning (2D or 3D).

CyberKnife

- Linac on a robotic arm.
- Very high doses.
- Breath tracking.

The Evolution of Radiotherapy

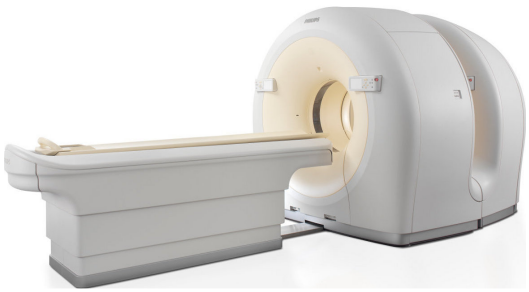
Surgical Strike

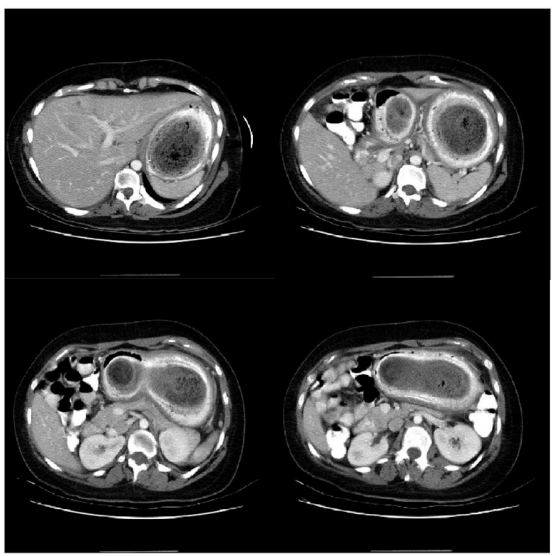
Main Problem

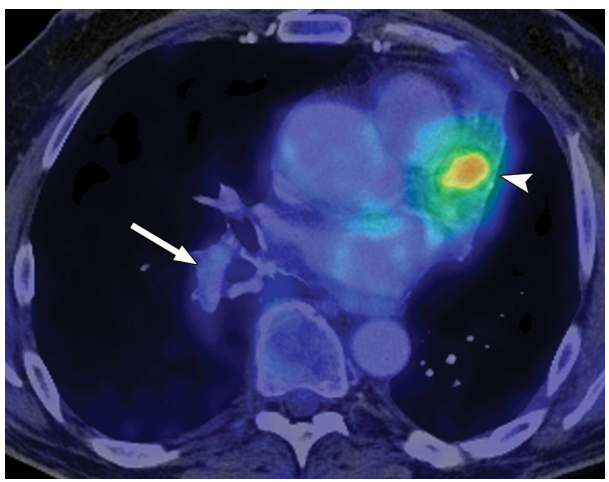
How to identify the target? $\Rightarrow$ **Medical Imaging**

Multimodal Medical Imaging for Radiotherapy

CT + **MRI** + **PET-CT**

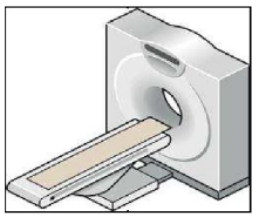




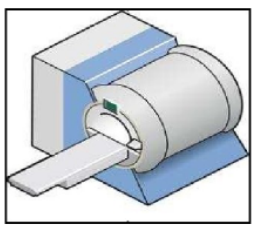


Overall Process

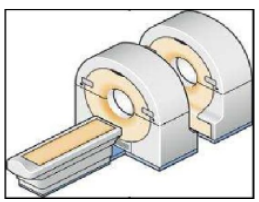
CT



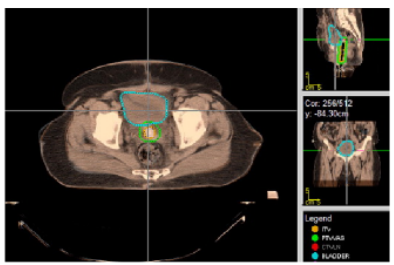
MRI



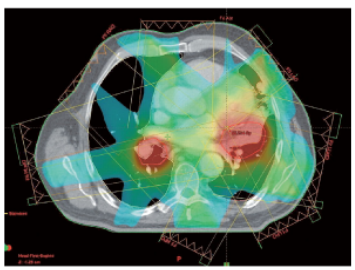
PET-CT



Contouring
(organs, tumor)



Ballistics
(optimization)



Elekta

Cyberknife

Software Challenges of Modern Radiotherapy

- Many images are produced and analyzed.
- Exchange of images between several medical departments.
- Each image is heavyweight ($\approx$ 512MB per 3D image).
- Many manufacturers are involved $\Rightarrow$
  - Proprietary, costly, closed software.
  - Limited interoperability.

What Is DICOM?

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1. File Format:

One image slice + Patient metadata

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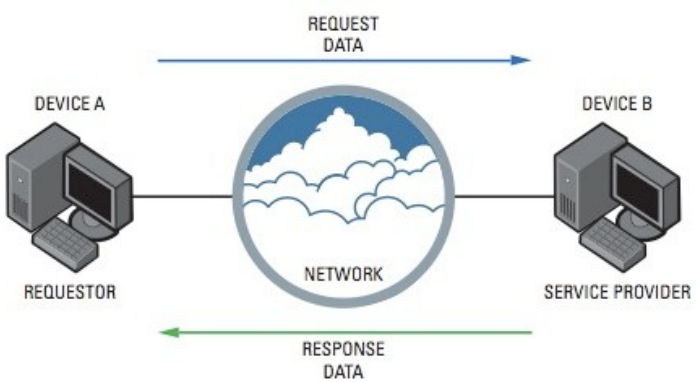
2. Network Protocol — Early example of Web services:



- Search remote images,
- Send local images,
- Retrieve remote images.

What Is DICOM?

Part of the Solution

- De-facto standard in medical imaging.
- Mature (30 years old).
- Supported by any medical device.

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Part of the Problem

- Large and complex (over 4000 pages).
- Old format and protocol (redundant with XML, SOAP,...).
- Huge number of files (3D images split slice-by-slice)
  $\Rightarrow$ Redundancies between DICOM files,
  $\Rightarrow$ Need for automated indexing.
- Not developer-friendly (complex parsing).

Main Open-Source Software for DICOM

DICOM Toolkits

- DCMTK (format, protocol),
- GDCM (format only).

DICOM Databases (aka. PACS)

- Dcm4chee,
- Dicoogle.

Main Open-Source Software for DICOM

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Limitations

- Close-to-metal (network administrators?).
- No indexing.
- Windows support.

DICOM Databases (aka. PACS)

- Dcm4chee,
- Dicoogle.

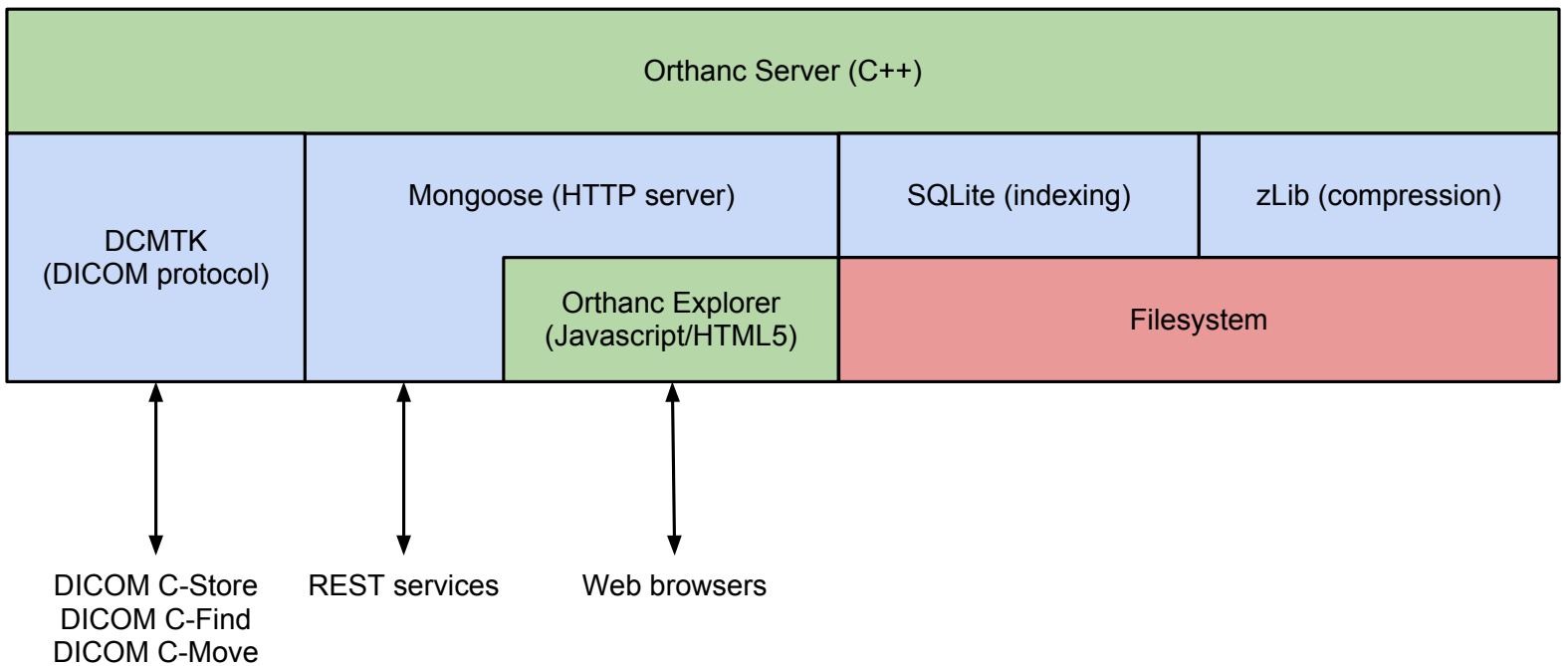
Limitations

- Heavyweight.
- Database administration.
- Still need a DICOM toolkit to automate tasks.

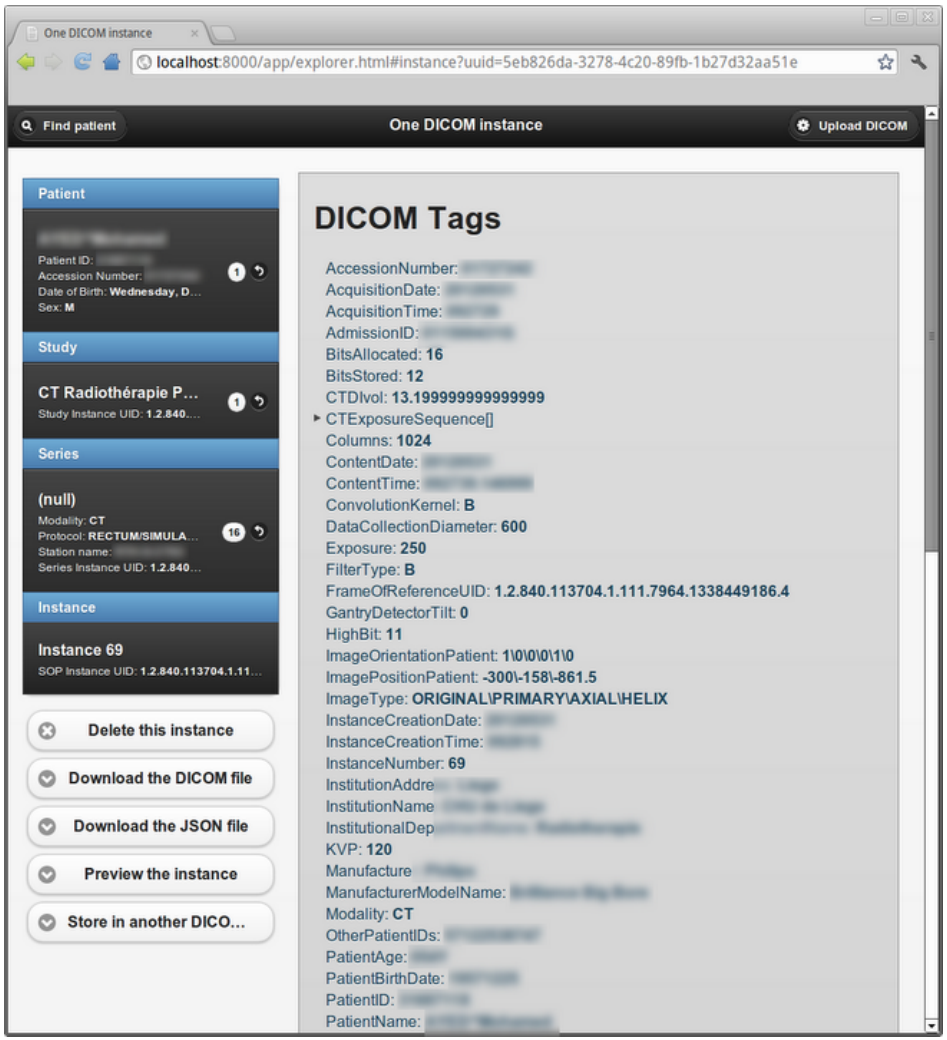
Philosophy

1. Compromise between a DICOM toolkit and a PACS.
2. Lightweight DICOM store (standalone, cross-platform).
3. Immediate to deploy on any PC (no external database).
4. RESTful API to DICOM format and protocol.
   $\Rightarrow$ DICOM scripting (network administrators).
5. Convert DICOM files to modern formats (JSON and PNG).
6. Simple Web interface to explore the content of the store.
7. ...And, of course, open-source :)

Software Architecture



Web Interface in Action



Features

- "Patient → Study → Series → Instance" transparent indexing.
- Preview of images inside the browser.
- Send to other DICOM modalities.
- Download ZIP files.
- Anonymization.

Scripting with Python — Automatic Bridge to the PACS

```
sys.path.append('Orthanc/Resources/Samples/Python')
from RestToolbox import *

# Event polling loop
current = 0
while True:
    # Wait for the occurrence of new events in Orthanc
    r = DoGet('http://localhost:8042/changes', { 'since' : current })

    # React when a new instance is received
    for change in r['Changes']:
        if change['ChangeType'] == 'NewInstance':

            # Send the new instance to the PACS
            instanceId = str(change['ID'])
            DoPost('http://localhost:8042/modalities/pacs/store', instanceId)

            # Remove the instance from Orthanc
            DoDelete('http://localhost:8042/instances/%s' % instanceId)

    current = r['Last']
    time.sleep(1)
```

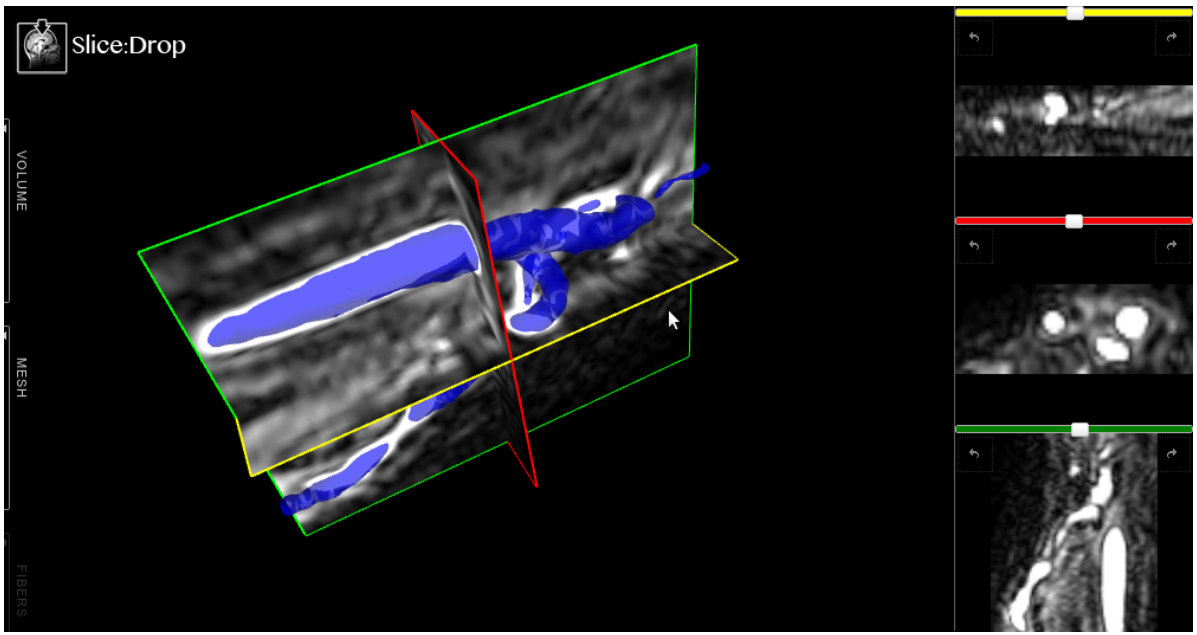
Current Applications of Orthanc

- DICOM buffer for transmission errors:
  - Nuclear Medicine $\rightarrow$ Radiotherapy,
  - Treatment Planning System $\rightarrow$ Treatment machines.
- Collect in-room images for adaptive radiotherapy research.
- Anonymization platform for clinical research with firms.
- Automated quality control of PET-CT scanners.
- Automated quantification of focal fibrosis on cardiac MRI.
- Mini-PACS on desktop computers $\Rightarrow$ medical and image processing research.

1. Introduction
   - What is Radiotherapy?
   - The Radiotherapy Process
   - DICOM Format and Protocol
2. Orthanc
   - Philosophy
   - Orthanc in Action
   - Current Applications
3. Conclusions
   - How to Contribute?
   - Summary

How to Contribute?

- Develop a professional, Web-based DICOM viewer (WebGL)
  $\Rightarrow$ MIP, PET/CT/MRI fusion, windowing, projection,...



- Port to OS X, RHEL and CentOS.
- FUSE filesystem on the top of the REST API.
- Support WADO, standardize WADO-RS (RESTful DICOM).
- Implement DICOM-RT primitives (for radiotherapy).
- Develop a Matlab/Octave toolbox.

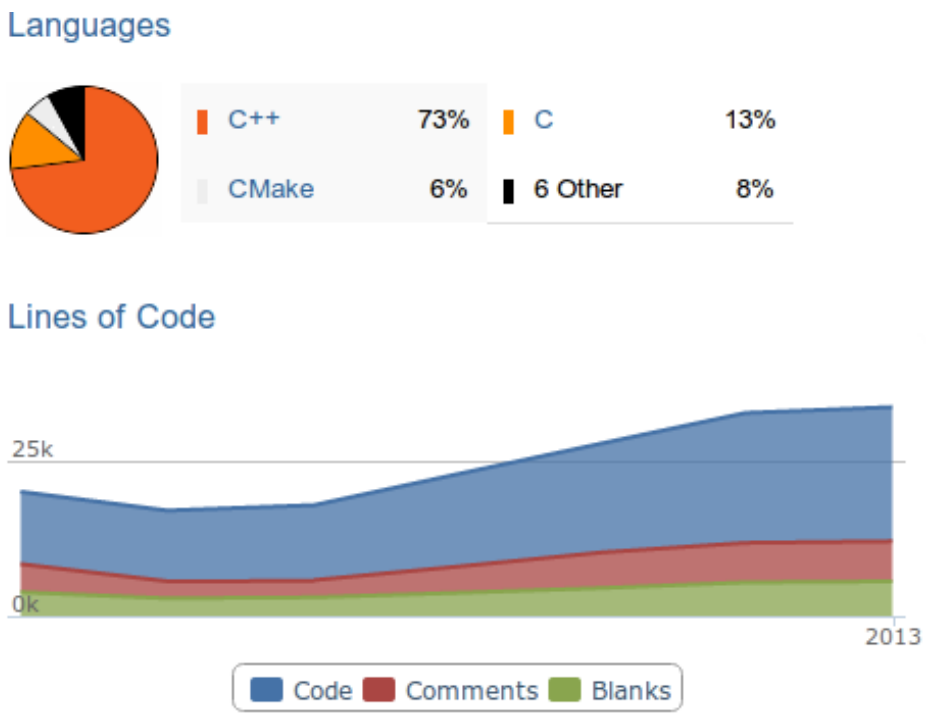
Summary

`https://orthanc.googlecode.com/`

- Open-source DICOM store.
- Lightweight, scriptable, versatile.
- Availability:
  - Part of Debian Med,
  - Fedora package waiting for approval,
  - Windows binaries.
- Publications: ISBI 2013, ESTRO 2013, 2 @ BHPA 2013.

Appendix

Ohloh Statistics



Focus on Automated Testing

- Continuous Integration Server,
- Unit testing,
- Integration tests through REST API,
- Valgrind,
- Trello to track developments.

Desirable Features for a Novel DICOM Viewer

- Web-based $\Rightarrow$ accessible from any PC in the hospital without installation.
- Cross-platform, lightweight (WebGL, XTK, Slice:Drop).
- Side-by-side display, link the two series of images (with zoom).
- Windowing (Hounsfield units, 16bpp).
- 3D view + 2D projections (axial, coronal, sagittal).
- PET/CT/MRI superposition and alignment (offsets).
- MIP rendering (Maximum Intensity Projection $\Leftrightarrow$ `EXT_blend_minmax`).
- Display DICOM-RT (doses and structures).
- Possibility to use non-destructive image compression.
- Speed, smoothness, stability, simplicity (of course).
- Other features: Consider OsiriX (*but OS X only!*).