Convergence in Digital Pathology data sharing

A standard recommendation for Digital Pathology Information Web-Services

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Disclaimer

Yves Sucaet and Wim Waelpput are co-founders and shareholders in Pathomation, a young innovative company founded in 2012. The company strives to offer the most comprehensive software platform for digital pathology possible. The focus is on integration, scalability, and user-friendliness. Pathomation implements digital pathology in a variety of use cases and scenarios.
Introduction

- In this presentation:
  - The main causes behind the DP evolution lag
  - The nature of the DP informative content
  - The well established inter-discipline standards are investigated

- The first “Digital Pathology Information Web-Services” (DPIWS) standard recommendation is introduced
Introduction:
A glimpse in DP evolution

- 45 years of evolution (just 3 slides!)

- Back in 1968:
  - The first pathology slides were digitized as black and white digital images
  - The digital images were transferred from Boston’s Logan Airport to Massachusetts General Hospital

- During the 70’s and 80’s:
  - Inadequate programming tools and computer technology held back DP

- During the 90’s:
  - Bursting IT and data transmission systems evolution sets the foundations of DP
Introduction: A glimpse in DP evolution

- **21st century:**
  - Fundamentally changed the way information is treated
  - Digitization became the doorstep in modern healthcare evolution
  - Digital cameras and hi-resolution scanners are of increasing importance
  - Huge storage capacities allow for high volumes of DP information handling
  - Ultra-high data transmission speeds allows for adequate amount of DP data sharing in near-real time*

*Yet:* DP lags behind other medical disciplines in novel ICT adoption (i.e. Radiology). WHY?
Introduction: A glimpse in DP evolution

- 21st century:
  - **Tele-Pathology** and distance collaboration becomes of increasing importance, both for
    - work-balancing and cost reduction, as well as for
    - optimized diagnoses through distant experts’ invocation
  - Establishment and adoption of **standards in DP information handling** and sharing becomes “Sine Qua Non”*

*In fact: One of the major obstacles in establishing and adopting effective telepathology processes overtime has been the lack of information brokerage standardization
DP evolution lag:

PATHOLOGY VS. RADIOLOGY
DP evolution lag:
Pathology vs Radiology

- **Radiology** usually works with live specimens
  - This called for “instances” of information to be acquired “on the spot” at first place, no alternatives provided

- **Pathology** usually works in specimen “samples” (biopsies, cytologies)
  - The “sample” glass constitutes itself a “take away” artifact to work upon, no copying or digitization was necessary to the traditional work-flow (Pathologists could live without it!)
DP evolution lag: Pathology vs Radiology

- **Radiology** is usually a *one-way process*
  - The patient (specimen) is scanned. Then the samples (scannings) are evaluated, with a small minority of exceptions

- **Pathology** has more *complex work-flow*
  - **More than one Pathologists’** opinions may be required to form the final diagnosis
  - **Additional stainings** may be required during the evaluation process; this poses constant interchange between the wet-lab and the Pathologists
  - RIS can not cope with DP workflow
DP Information:

DP CONTENT OVERVIEW
DP informative content:

DP informative content overview

- DP informative content, consists of **two major parts**, i.e.
  - The **images**
  - The **annotations**

- To handle and distribute the content as a whole, **one additional part is needed**:
  - The **data binding** and **transfer structure**
DP informative content:
The images

- Stained slides are digitized through digital photography and scanning
- DP images resolution usually ranges from tenths to hundredths of thousands pixels per dimension (i.e. Giga-pixel scale*)

*Issue: Efficient handling, sharing and collaborating over networks
Various software techniques* are being employed to deliver efficient handling of the images, e.g.:
- The widely utilized “Pyramidal Format” consisting of pre-computed scaled versions of the original scan
- The “Overlapping tiles” format, consisting of varying zoom tiles overlapping in the image space, etc.

*Issue: Proprietary, vendor-locked techniques in the majority of the cases
The images

- Various file storage formats i.e. Leica SCN, 3D Histech MRXS, Hamamatsu NDPI, Aperio SVS, Olympus ZVI, TIFF …

- Various compression formats JPEG, JPEG2000, PNG, LZW and DEFLATE are utilized. Colors are usually encoded in RGB and gray scale.
DP informative content: The annotations

- DP annotations consists of:
  - Free textual comments
  - Semi / fully structured domain-specific text in XML envelopes
  - Binding reference of the texts to the:
    - initial specimen
    - slide
    - image
    - Regions Of Interest (ROI’s) within the image

*Issue: Adequate sharing and semantic interoperability between OEM software
Building the DP data binding and transfer structure:

EXISTING WELL-ESTABLISHED STANDARDS
DP data binding and transfer structure:
Existing well-established standards

- Relevant standards do exist and are well-established as well*!
  
  - DP imagery information handling and distribution may be covered by specific portions of the DICOM (Digital Imaging and Communications in Medicine) standard

  - DP annotating information may be adequately modeled through the OME (Open Microscopy Environment)

* Each bearing attractive features and drawbacks
DP data binding and transfer structure:
Existing well - established standards

- Relevant standards do exist and are well - established as well!
  
  Yet, DP information is found to bear significant structural similarities to Geographical information Systems, the sharing and distribution of which has been highly standardized since decades through the Open Geospatial Consortium i.e.:
  
  - WMS (Web Map Service) &
  - WFS (Web Feature Service) standards
Existing well-established standards

**DP Imagery information handling in DICOM**

- **Publishing of generic medical imagery** is being addressed in a number of sections of the DICOM standard, two of which directly guide the software development process, namely:
  - **Part 3**: Information Object Definitions and
  - **Part 18**: Web Access to DICOM Persistent Objects (WADO)

* under the “VL Microscopic Image Information Object Definition Content Constraints” DICOM PS 3 A.32.2 and “VL Whole Slide Microscopy IOD Content Constraints” PS3 A32.8 PS 3.3 - 2011 p.195 PS 3.3 - 2011 p.203 considering supp. 145

** URL request/response procedure for multi-frame structured images
Existing well-established standards
DP Imagery information handling in DICOM

- WADO Request / Response process

WADO URL Request for retrieving a region of a single image

https://aspradio/imageaccess.js?requestType=WADO
&studyUID=1.2.250.1.59.40211.12345678.678910
&seriesUID=1.2.250.1.59.40211.789001276.14556172.67789
&objectUID=1.2.250.1.59.40211.2678810.87991028.899772.2
&contentType=image%2Fjp2;level=1,image%2Fjpeg;q=0.5
&annotation=patient,technique
&columns=400
&rows=300
&region=0.3,0.4,0.5,0.5
>windowCenter=-1000
>windowWidth=2500
Existing well-established standards
DP Imagery information handling in DICOM

- **THE drawback:**
  - DICOM response to the above structured request is an image with all annotations being rendered (“burned”) on the image!
    
    (Think of the case the client wishes to update the annotation…)

No method for requesting and retrieving meta-data annotations in a form other than imagery is exclusively defined in DICOM WADO.

This kind of response though is defined within the **Web Feature Service standard**, where the equivalent of an annotation is the “Feature” element.

In addition, Open Microscopy Environment provides with a detailed and well structured definition for annotations on digital pathology images.
Existing well-established standards

The Open Microscopy Environment (OME) annotations

- OME is the dominant open-source software and data format for the storage and manipulation of biological microscopy data
  - vastly supports and standardizes biological Microscopy Annotations Structuring, in the form of 2-D and 3-D Regions of Interest
  - tackles biological microscopy Data Modeling based on well-structured XML for meta-data description
Existing well-established standards

The Open Microscopy Environment (OME) annotations

The Structure Annotation branch of the OME Model

OME defines in great detail, advanced annotation structures
Existing well-established standards
The Open Microscopy Environment (OME) annotations

Drawback:

- The OMERO Server (the OME implementation for DP):
  - is way too complex and specific in implementation details to be considered as a wide web-standard for DP information
  - does not provide with a minimal set of platform independent operations

- Existing well-established standards of proven validity (i.e. WMS and WFS) define the desired minimum functionality in a much more clear, implementation independent and robust manner.
Existing well-established standards
Open Geospatial Consortium's WFS

- The **Web Feature Services** specification defines **interfaces for data manipulation operations** of geographic features.

- The operations include the ability to:
  - get or query features based on both spatial and non-spatial constraints
  - create new feature instances
  - delete a feature instance
  - update a feature instance
Existing well-established standards
Open Geospatial Consortium's WFS

- **Web Map & Web Feature Services** handle *multiple layers* of both raster images and vector data (polygons and various forms of related meta-data)*,

  making it the ideal standard interface:

  - To *uniformly query and retrieve* composite large scale images, consisting of superimposed multi-resolution raster images, vector objects and textual annotation layers

  - To *uniformly pass the results to the client side* across the web in spite of the complexity of the recordings

* Exceeding DICOM capabilities
Digital Pathology Information Web-Services (DPIWS)

STANDARD RECOMMENDATION
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS is **NOT**: 

- A standard for describing the DP content, encoding, compression, formatting and storage details
- A standard for describing annotations
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS IS:

- A standard Request-Response interface for the exchange of Digital Pathology Information over the web

- It clearly defines a minimum set of operations a DP content server has to be able to provide, for the DP content to be meaningfully exchanged

- DPIWS is platform-independent, image and annotation format-agnostic
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS IS:

- A set of URL “request” definitions
  
  +

- A set of “server response” definitions

Suitable for sharing DP imagery info and annotations
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

Hospital / Pathology Lab

- Slides Scanning
  - SCN, MRXS, NDPI, Tiff, Jpeg 2000, etc.

- DP Images & Annotations
  - In-house Repository
    - DICOM, OME, .... Compliant

- DP Information Server (TCP/IP)

Internal & External DP Info Sharing

- Acquire
- Annotate
- Diagnose
- Update

- Internal & External DP Info Sharing

- DP Information Reporting
  - DPIWS - HL7 agent

- LIS / HIS

- Pathologist
  - Digital cockpits
DPIWS builds upon the well-established standards

**DPIWS Standard Recommendation**

- **Web Feature Services & Web Map Services:** Image & Metadata Discovery, Web Transactions implementation
- **Open Microscopy Environment (OME):** Annotations & Regions of Interest (RoI's) within microscopy images
- **DICOM/DICOM WADO:** Image handling / Standard URL Requests
Digital Pathology Information Web-Services (DPIWS)
Standard Recommendation

DPIWS transactions definition:

- GetCapabilities
- GetNamespaces
- GetImages
- GetImageInfo
- GetImage
- GetAnnotations
- InsertAnnotation
- DeleteAnnotation
- UpdateAnnotation
Digital Pathology Information Web-Services (DPIWS)
Standard Recommendation

DPIWS transactions definition:

- GetCapabilities
  - Returns DP server version & administrator information
    - Client Request: [http://localhost/?Request=GetCapabilities](http://localhost/?Request=GetCapabilities)

Server Response:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Capabilities version="1.0.0">
  <Service>
    <Name>DPIWS</Name>
    <Title>Digital Pathology Information Web Service</Title>
    <Abstract>A compliant implementation of DPIWS</Abstract>
    <ContactInformation>
      <ContactPersonPrimary/>
      <ContactOrganization>Digital Pathology INC</ContactOrganization>
      <ContactAddress/>
      <AddressType>Cloud</AddressType>
      <City/>;
      <StateOrProvince/>;
      <PostalCode/>;
      <Country>Somewhere</Country>
      <ContactVoiceTelephone/>
      <ContactFacsimileTelephone/>
      <ContactElectronicMailAddress>claudius.petomaus@gmail.com</ContactElectronicMailAddress>
      <AccessConstraints/></AccessConstraints>
    </ContactInformation>
  </Service>
</Capabilities>
```
Digital Pathology Information Web-Services (DPIWS)
Standard Recommendation

DPIWS transactions definition:

- **GetNamespaces**
  - Without parameters it returns the root namespaces available in the DP server.
  - If a namespace is provided as parameter, it returns it’s direct sub namespaces
    - [http://localhost/?Request=GetNamespaces](http://localhost/?Request=GetNamespaces)

Server Response:
DPIWS transactions definition:

- **GetImages**
  - Returns the names of the images under the specified namespace

**Server Response:**

![Image Management Interface](image-url)
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS transactions definition:

- **GetImageInfo**
  - Returns parameters of a specific image, image type and size, resolution information and available dimensions - i.e. time frames, z-stacks, channels

Server Response:

- [Image of the response](image.png)
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS transactions definition:

- **GetImage**
  - Returns a region of an image scaled to fit a given viewport.

  ```
  http://localhost/?Request=GetImage
  &image=Pathomation:PublicImages:image1.tiff
  &frames=0,1,2,5
  &bbox=100,500,1000,2500
  &contentType=image%2Fjp2;level=1,image%2Fjpeg;q=0.5
  &width=500
  &height=400
  &annotations=true
  ```
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS transactions definition:

Server GetImage Response depiction
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS transactions definition:

- **GetAnnotations**
  - Returns the annotations of an image in an XML envelope

- **InsertAnnotation**
  - Inserts an annotation under an image
    - POST request with the following parameters:
      - Image, annotation, content
Digital Pathology Information Web-Services (DPIWS) Standard Recommendation

DPIWS transactions definition:

- **DeleteAnnotation**
  - Deletes an image's annotation

- **UpdateAnnotation**
  - Updates an image's annotation
    - POST request with the following parameters:
      - Image, annotation, content
Digital Pathology Information Web-Services (DPIWS)
Standard Recommendation

DPIWS transactions definition:

Server GetAnnotations Response depiction
Digital Pathology Information Web-Services (DPIWS)
Standard Recommendation

DPIWS:

- Is an independent recommendation*, designed by Pathomation®. It is applied, tested, operating, and evolved on real-life DP data through the Pathomation cloud service®.

- Conforms to and expands DICOM WADO

- It utilizes the OME ROI envelop for annotations exchange

- It defines the supported transaction types according to WFS & WMS

*DPIWS is currently in the status of “Standard Draft”.
Digital Pathology Information Web-Services (DPIWS)
Standard Recommendation

Building DPIWS - compliant services will eventually eliminate the risk of long-term vendor content locking, thus boosting the digital transition in the field of pathology.

*DPIWS is currently in the status of “Standard Draft”.*
Recommended Resources

**DICOM**
ftp://medical.nema.org/medical/dicom/final/sup145_ft.pdf

**OME**
http://www.openmicroscopy.org/site/support/ome-model/
OME Model and Formats 2013-06 Documentation
http://www.openmicroscopy.org/site/support/ome-model/developers/structured-annotations.html
OME Structured Annotations
http://www.openmicroscopy.org/site/support/ome-model/developers/roi.html
OME ROI Model
http://www.openmicroscopy.org/site/products/omero
OMERO Server Implementation

**WFS & WMS**
http://www.opengeospatial.org/standards/wms
http://www.opengeospatial.org/standards/wfs

Open Geospatial Consortium Inc. Date: 2010-11-02  Reference number of this OpenGIS® Project Document: OGC 09-025r1 and ISO/DIS 19142 Version: 2.0.0  Category: OpenGIS® Implementation
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Digital Pathology

Series: SpringerBriefs in Computer Science

- Reviews the emerging field of digital pathology
- Describes the visualization, management, evaluation, comparison, archiving and dissemination of 2D and 3D specimens in digital form
- Discusses the challenges, solutions and benefits of implementing the use of digital pathology for research, education, clinical diagnosis and patient management

Digital pathology has experienced exponential growth, in terms of its technology and applications, since its inception just over a decade ago. Though it has yet to be approved for primary diagnostics, its values as a teaching tool, facilitator of second opinions and quality assurance reviews, and research are becoming, if not already, undeniable. It also offers the hope of providing pathology consultant and educational services to underserved areas, including regions of the world that could not possibly sustain this level of services otherwise. And this is just the beginning, as its adoption by the also rapidly-emerging fields of medical systems biology and 3D tissue imaging indicate.