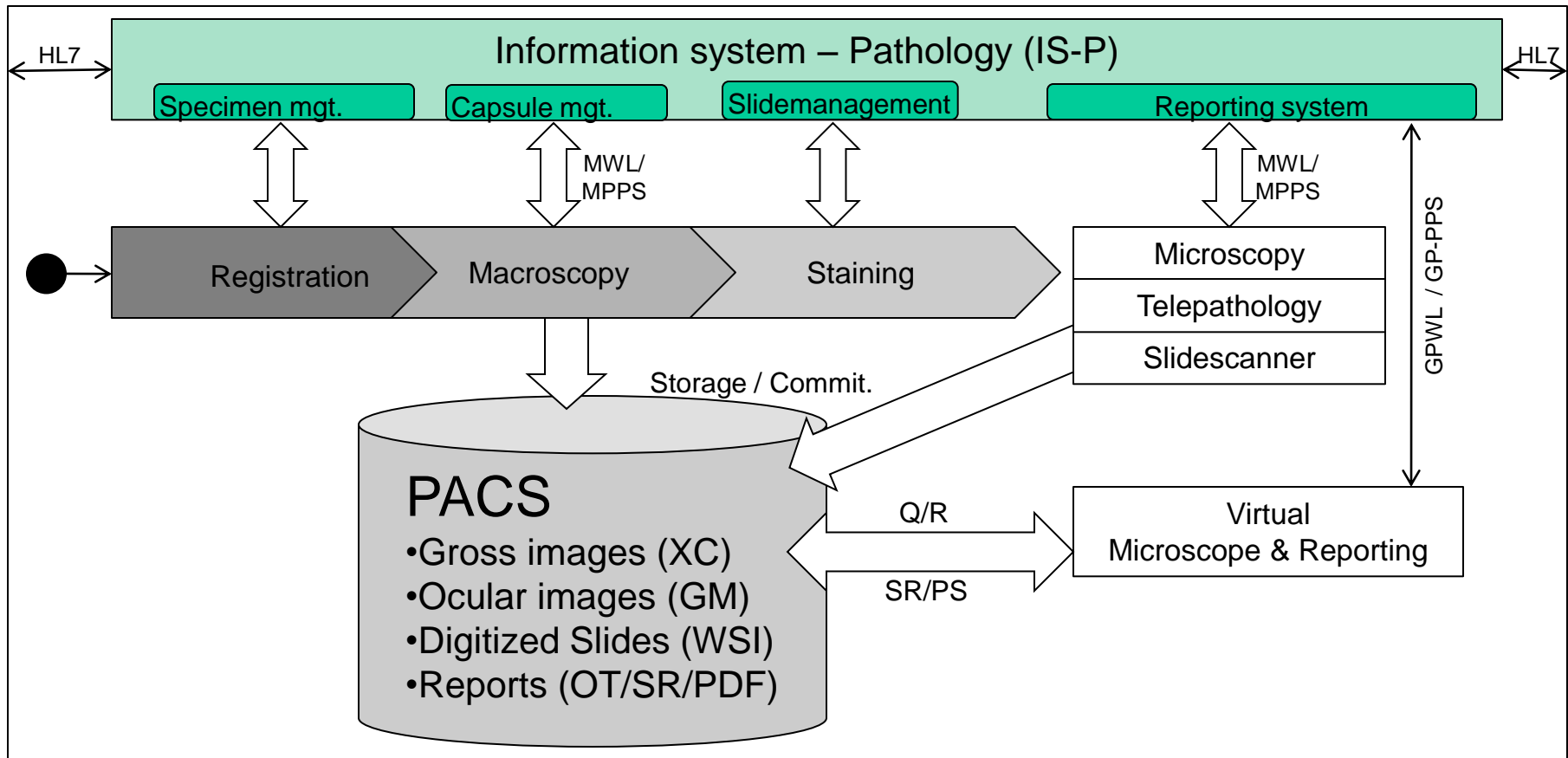

DICOM-compatible compression of WSI and diagnostic evaluation

R. Zwönitzer, H. Hofmann, A. Roessner , T. Kalinski

2nd European Workshop in Tissue Imaging and Analysis
June 25-26, 2010 - Heidelberg



Overview Digital Pathology (DP)



1. Future save integration in clinical infrastructure through DICOM
2. Organization of documents within a scalable information model (IM)
3. Query and retrieve out of this IM → Image distribution

Modality Worklist (MWL) – Specimen Identification

	SPCode	Modalität	Station	AE	Befunder	Behälter	Beschriftung	Präparat	Acc.No.	Ort
1		XC	Grosser Zuschnitt	Zuschnitt-A	Dr. Kalinski	Transportbehälter	H4487/03	H4487/03-3	ACC12348	
2	Multiangel 16 Gradteile	XC	AV Zentrum	FotoAcq-A	Dr. Kalinski	Glasbehälter	I12/97	H12/97-1	ACC12349	
3		GM	Mikroskop-B	WSIACQ-B	Dr. Kalinski	Objekträger Glas	H378/04	H378/04-1C4	ACC12347	
4	WSI Schichtdicke ein Mü	SM	Hamamatsu-A	WSIACQ-A	Dr. Kalinski	Objekträger Glas	H238/09	H14532/09-2A3	ACC12345	
5	WSI Schichtdicke ein Mü	SM	Hamamatsu-A	WSIACQ-A	Dr. Kalinski	Objekträger Glas	H238/09	H14532/09-1B1	ACC12346	


```

...E 0512 (8) Container Identifier (LO:1) H4487/03
+...E 0513 (104) Issuer of the Container Identifier Sequence (SQ:1) unassigned
+...E 0518 (74) Container Type Code Sequence (SQ:1) unassigned
...E 051A (18) Container Description (LO:1) Transportbehälter
-...E 0560 (312) Specimen Description Sequence (SQ:1) unassigned
  -P LoadFromStream
    -G Group 0040
      +...E 0000 (4) Group Length (UL:1) 292
      ...E 0551 (10) Specimen Identifier (LO:1) H4487/03-3
      ...E 0554 (24) Specimen UID (UI:1) 1.11365836.1300.1004.1.3
      +...E 0562 (104) Issuer of the Specimen Identifier Sequence (SQ:1) unassigned
      +...E 059A (68) Specimen Type Code Sequence (SQ:1) unassigned
      ...E 0600 (6) Specimen Short Description (LO:1) Leber
      ...E 0602 (8) Specimen Detailed Description (UT:1) proximal
      ...E 0610 (0) Specimen Preparation Sequence (SQ:1) unassigned
...E 1001 (8) RP-Id (SH:1) RP12348
...E 1003 (0) RP-Priority (SH:1) unassigned
  
```

- Specimen information and workflow communication according to DICOM requires extensions from Supplement 122.

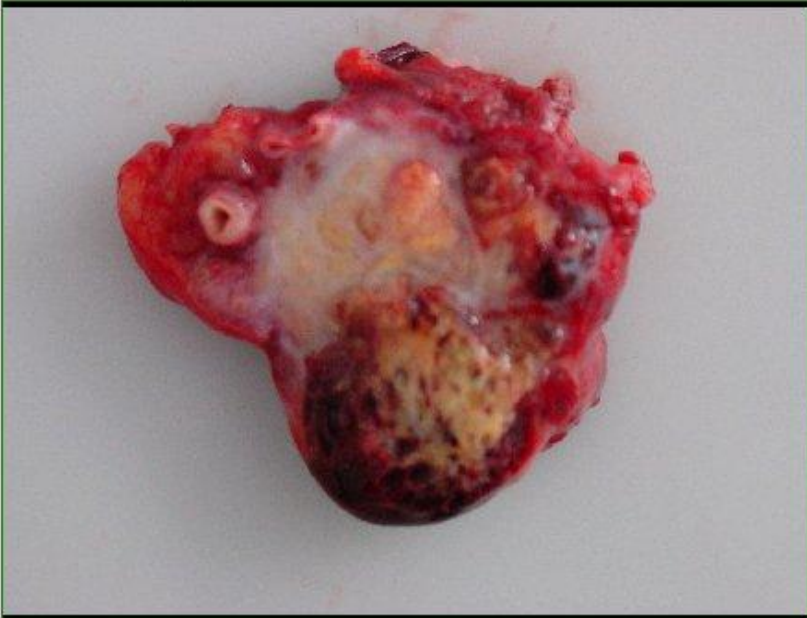
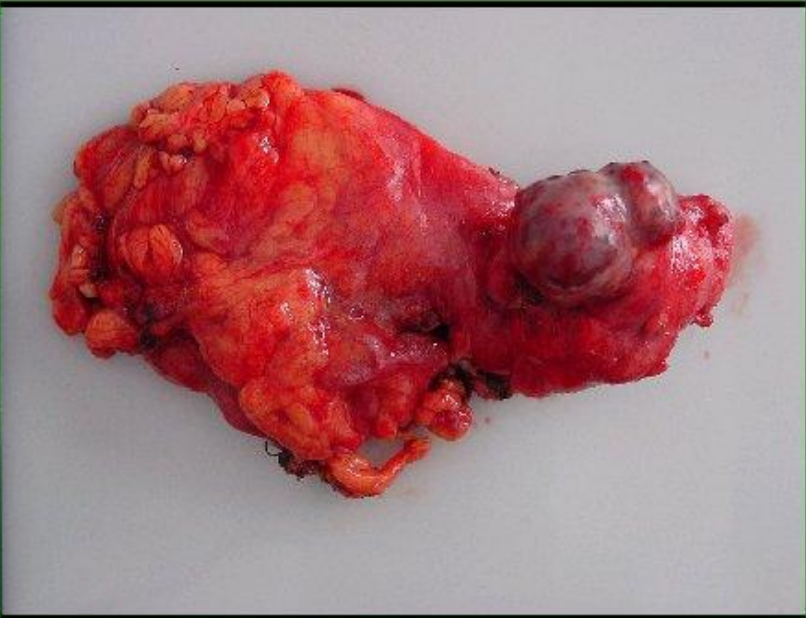
Macroscopic Images (Clinic)

PATHO

- Routine Patient 02.01.1960 (RP1) >Created<
- 07.05.2009 Macrofotografie (RP12348) >Created<
- 02.05.2009 Röntgen Dig.3.li. (1) >Changed<
- Direktor Karl Heinz Maelzer 12.11.1923 (KHM1) >Created<
- Erwin Lindemann Rentner 02.05.1909 (EL1) >Created<
- Ausbildungs Präparat 02.01.1960 (AP1) >Created<

Serien-No	Modalität	Bild-No
<input type="checkbox"/> 1 >Created<	XC	1
<input checked="" type="checkbox"/> 1 >Created<	XC	2
<input checked="" type="checkbox"/> 1 >Created<	XC	3

XC 17:13:13 (1)[1]

- DICOM Class Visible Light Photographic is sufficient
- Specimen ids required → Supplement 122

Macroscopic Images (Teaching & Learning)

The screenshot shows a DICOM viewer interface. On the left, a tree view displays a folder structure under 'PATHO', including 'Routine Patient 02.01.1960 (RP1) >Created<', 'Direktor Karl Heinz Maelzer 12.11.1923 (KHM1) >Created<', 'Erwin Lindemann Rentner 02.05.1909 (EL1) >Created<', 'Ausbildungs Präparat 02.01.1960 (AP1) >Created<', and '07.05.2009 Macrofotografie (RP12349) >Created<'. The selected folder is 'Multiangel 16 Gradteile XC 17:16:31 (1) >Created<'. On the right, a table lists image details:

Bild-No	Spalten	Zeilen	Media Storage SOP Class UID
<input checked="" type="checkbox"/> 1 >Created<	1441	2848	'VL Photographic Image Storage (I
<input checked="" type="checkbox"/> 2 >Created<	1441	2848	'VL Photographic Image Storage (I
<input type="checkbox"/> 3 >Created<	1441	2848	'VL Photographic Image Storage (I
<input type="checkbox"/> 4 >Created<	1441	2848	'VL Photographic Image Storage (I
<input type="checkbox"/> 5 >Created<	1441	2848	'VL Photographic Image Storage (I

Below the table, the viewer displays two side-by-side images of a specimen (a yellowish, curved object) inside a clear glass container. The left image shows the specimen from a slightly different angle than the right image.

- DICOM Class Visible Light Photographic is not sufficient.
- Multi frame module needed

Microscopic Ocular Images

The screenshot displays a DICOM viewer interface. On the left, a tree view shows a folder named 'PATHO' containing several patient folders, including '07.05.2009 Microfotografie (RP12347)'. A sub-folder 'GM 17:15:23 (1)' is selected. On the right, a table lists the contents of this folder:

Bild-No	Spalten	Zeilen	Media Storage SOP Class UID
<input checked="" type="checkbox"/> 1 >Created<	1280	1000	'VL Microscopic Image Storage (I
<input checked="" type="checkbox"/> 2 >Created<	1280	1000	'VL Microscopic Image Storage (I
<input type="checkbox"/> 3 >Created<	1280	1000	'VL Microscopic Image Storage (I

Below the table, two side-by-side images are shown. The left image is a low-magnification view of a histological slide, showing a large area of tissue. The right image is a high-magnification view of the same tissue, showing individual cells with prominent nuclei and cytoplasm.

- DICOM Class Visible Light Microscopic is sufficient
- Single images in series

Whole Slide Images (WSI)

The screenshot displays a DICOM viewer interface for Whole Slide Images (WSI). The left pane shows a file tree under the 'PATHO' directory, with the selected folder being 'WSI Schichtdicke ein Mü SM 17:14:10 (1)'. The right pane contains a table with the following data:

Bild-No	Spalten	Zeilen	Media Storage SOP Class UID
<input checked="" type="checkbox"/> 1 >Created<	1204	412	'VL Slide-Coordinates Microscopic Image
<input checked="" type="checkbox"/> 2 >Created<	9216	8768	'VL Slide-Coordinates Microscopic Image

The main viewing area shows two panels. The left panel is a low-resolution thumbnail of the slide, and the right panel is a high-resolution view of the tissue, showing pink-stained cells and structures.

Whole Slide Images (WSI)

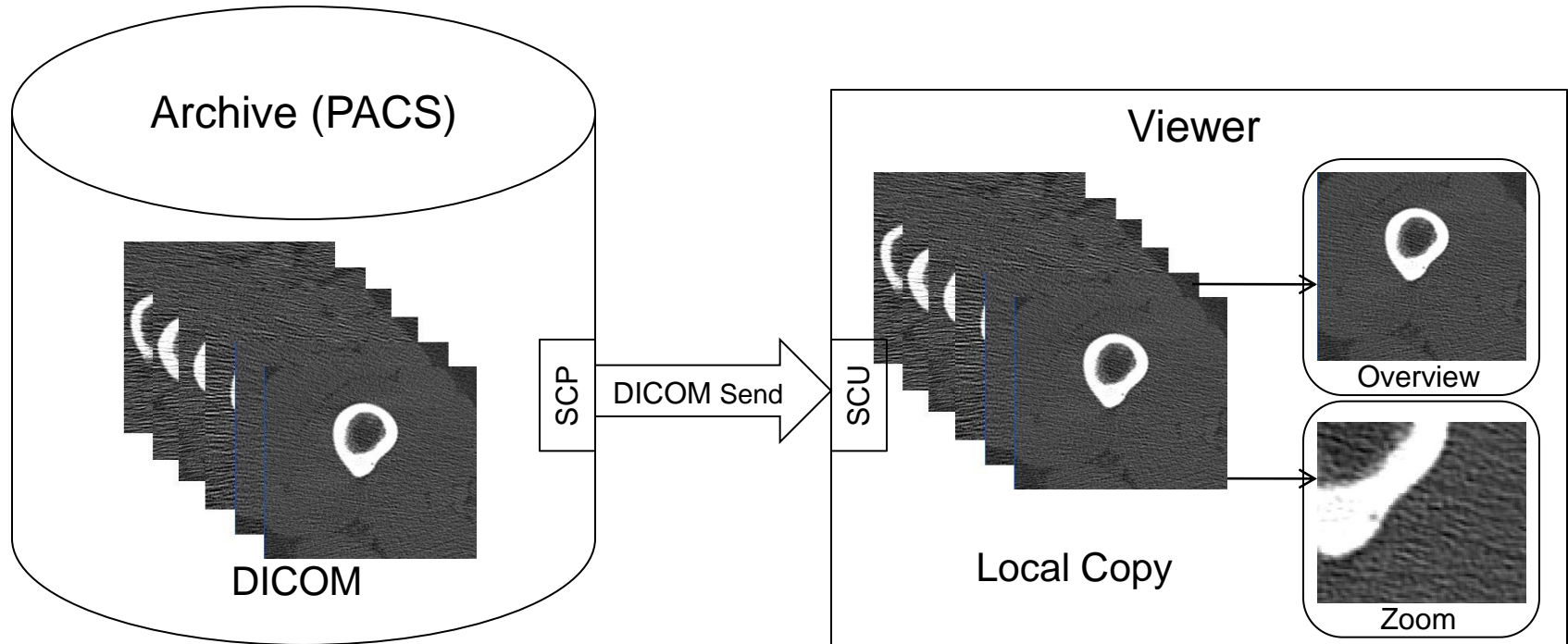
The screenshot shows a DICOM viewer interface. On the left, a file tree under 'PATHO' shows a folder for '07.05.2009 WSI-Scan (RP12345)'. The main window displays a histological slide. The 'Eigenschaften' panel on the right shows the following metadata:

- Class: 1.2.840.10008.5.1.4.1.1.7 (Secondary Capture Image Storage)
- IOD: A.8.1 (SC Image) Mandatory
- Module: C.7.6.3 (Image Pixel) Mandatory
- Entity: Large Rows (UL) VM:1 VR:UL Superfluously by Condition ,n00280010 :

The 'Large Rows (UL)' tag (0510) and 'Large Cols (UL)' tag (0511) are circled in red in the metadata list.

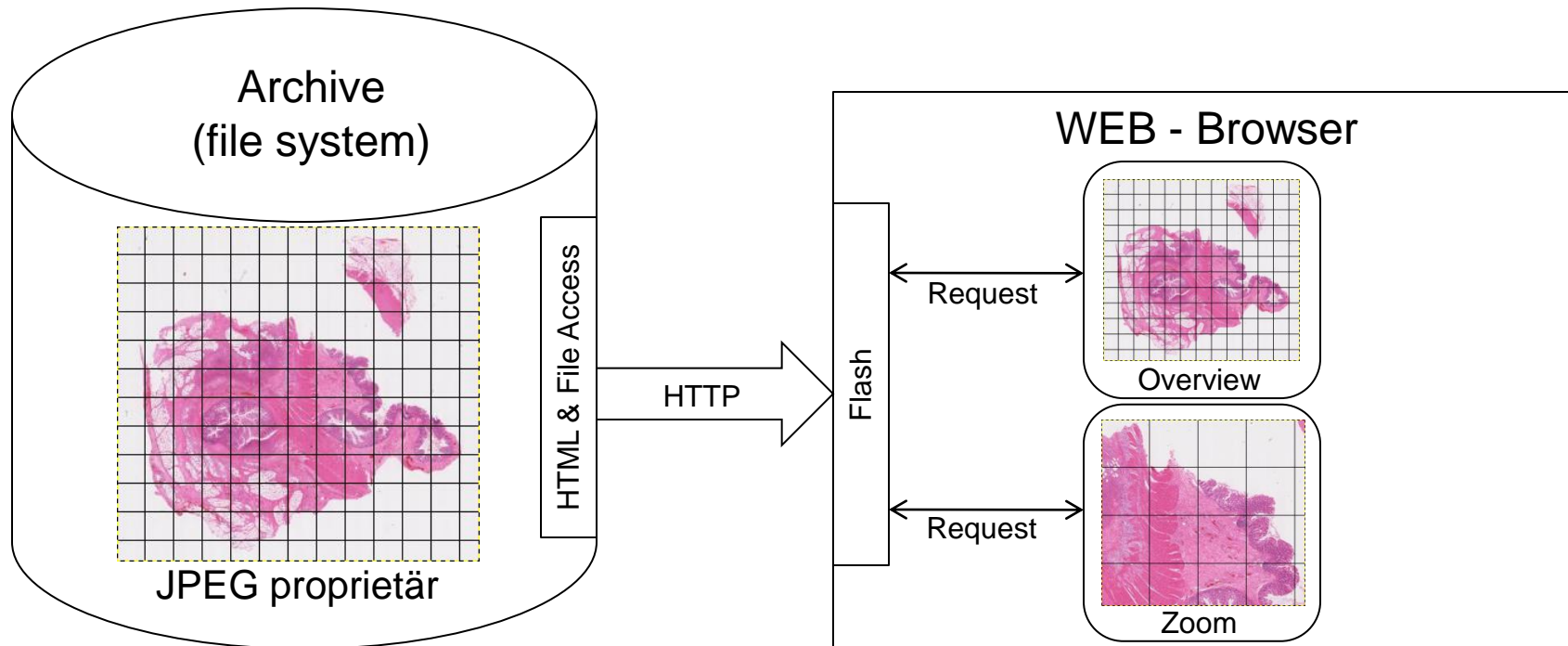
- DICOM Class Visible Light Slide Coordinates is not sufficient
- Multi frame module and Large-Dimension-Tags needed

Radiologic Image Distribution - DICOM (store and forward)



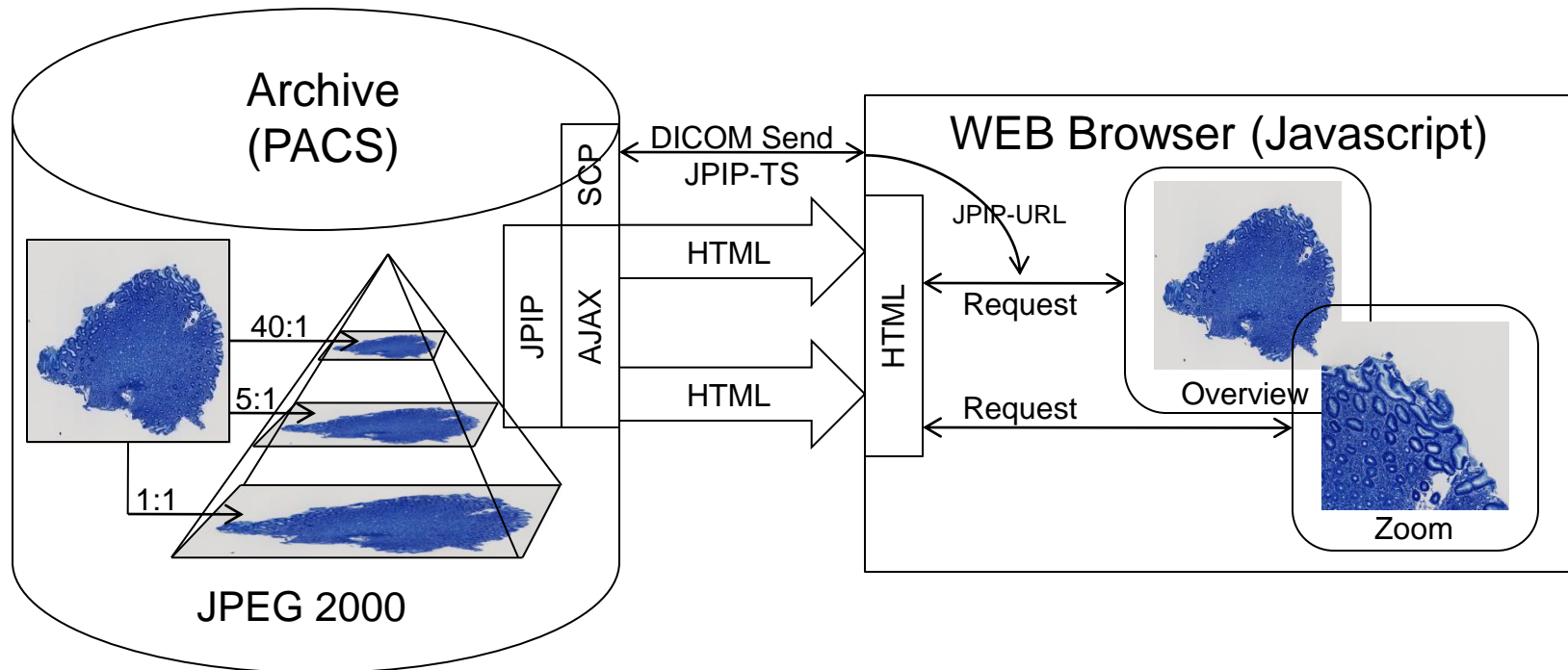
- Display after complete transport only
- Store and forward is not sufficient for very large WSI images
- Integration of JPIP in DICOM solves this problem by streaming

Image Distribution „Fractioning“ (e.g. silverZoom , Zoomify)



- Image fractioning results in higher resource loads
 - Problems possible by active parts in browser (e.g. Flash)
 - Non-standard format und protocol, no integration in DICOM
- Not sufficient for future save archiving huge amount of data



Image Distribution - JPEG2000 / JPIP (AJAX)



- Image calculation on demand on server.
 - Access to JPEG2000 images through JPIP or directly.
 - Parallel usage for intra- and internet possible, one format only.
- Sufficient for intranet and internet but elaboration on server.

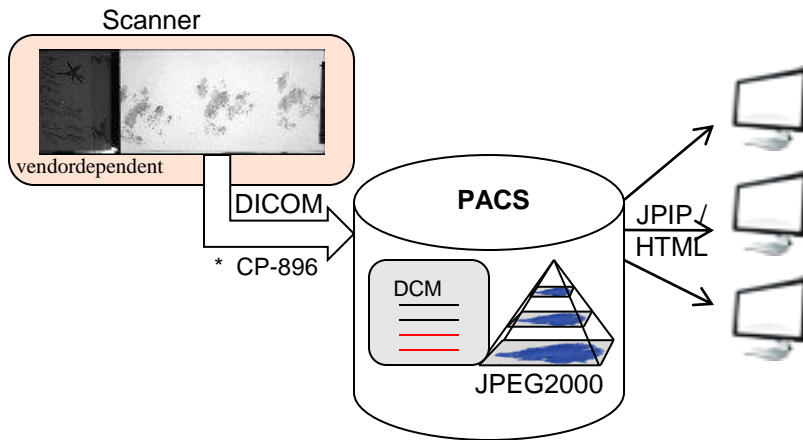
Technical Requirements Image Compression

- Integration in DICOM
 - Image quality (over all lossy)
 - Efficiency
 - Effort for coding and decoding
 - Data organization und flexibility
 - Growing amounts, all sizes and kinds of images
 - Autonomy
 - Future save
 - Scalable with use case
 - Supports image distribution with progressive requests
 - Only one Algorithm (lossy and lossless)
- Format supports all criteria

	 R=64:1	 R=64:1
	JPEG2000	JPEG
	yes	yes
	1	3
	3	1
	1	5
	2	4
	1	4
	1	5
	yes	no

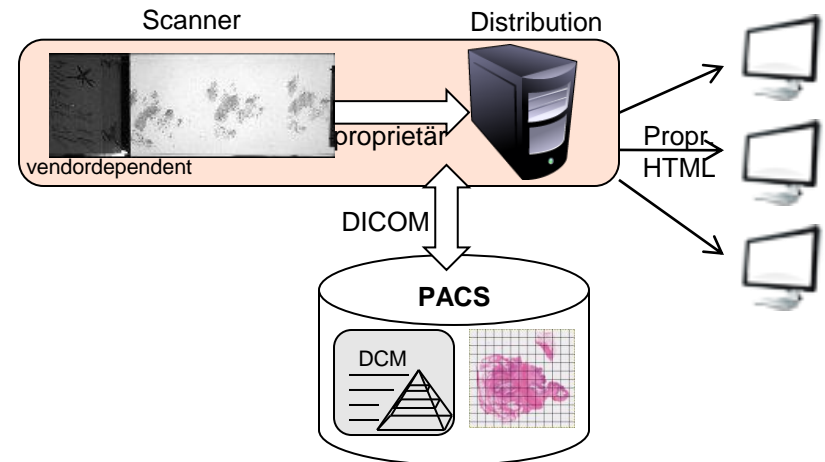
Current WSI Approaches

„Large Dimensions“



- New tags for large dimensions or extended negotiation (*)
- DICOM Header & JPEG2000
- Image distribution out of archive
- Vendor independent
- Synergies with other image classes

Supplement 145

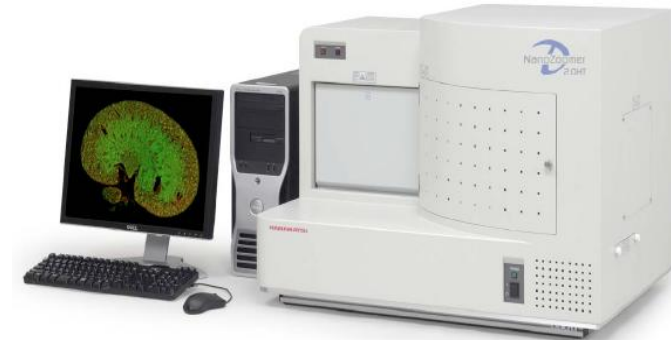
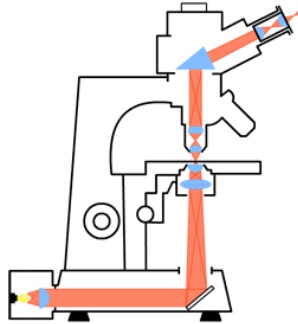


- Fractions instead of huge images
- DICOM Header contains progressive information
- Extra distribution needed
- Dependency on propr. distribution
- No synergy effects

Summary so far ...

- **DICOM is usable for Digital Pathology**
 - Supplement 122 functional
 - Worklist and MPPS are sufficient
 - Existing image classes with multi frame applicable
 - JPEG2000 integration for lossy encoding and streaming
- **JPEG2000**
 - Image distribution for all image types and transports with JPIP / AJAX
 - Efficiency depends on optimization
- **DICOM WSI**
 - Supplement 145 introduces image fractioning
 - Large dimensions anticipated, even optional
 - Usability of old archives for WSI image distribution doubtful
- **Diagnostic Evaluation**
 - Lossy compression up to 75:1 applicable to biopsy images
 - Other image contents to be evaluated

Can we trust virtual microscopy in diagnostic pathology?



Essential functions of conventional microscopes:

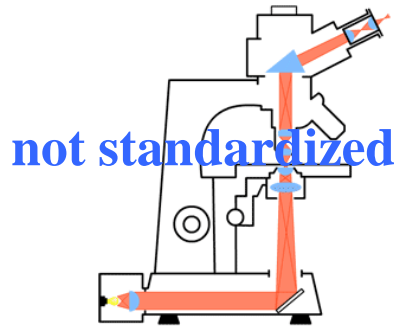
- Magnification
- Focusing
- Polarizing

Scanner conditions (as provided):

- Uncompressed raw data
- Resolution (0,23 $\mu\text{m}/\text{pixel}$)
- Multiplane images

→ Comparative investigations on the diagnostic accuracy using conventional microscopy or virtual microscopy with different qualities

Can we trust virtual microscopy in diagnostic pathology?



Essential functions of
conventional microscopes:

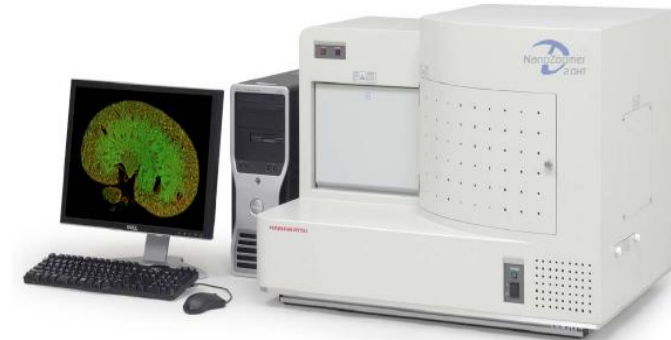
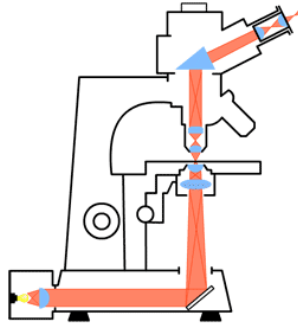
- Magnification
- Focusing
- Polarizing

Scanner conditions (as provided):

- Uncompressed raw data
- Resolution (0,23 $\mu\text{m}/\text{pixel}$)
- Multiplane images

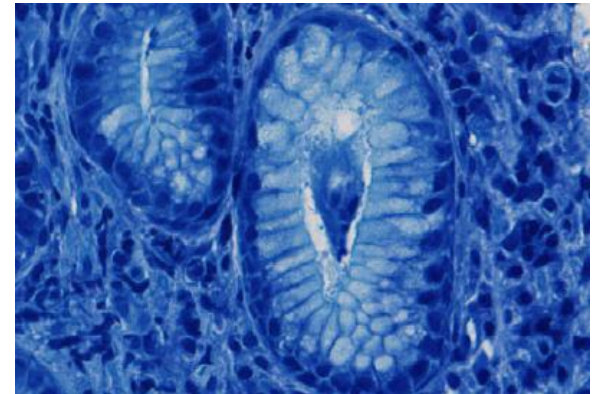
→ Comparative investigations on the diagnostic accuracy using conventional microscopy or virtual microscopy with different qualities

To begin with... Helicobacter gastritis.



Updated Sydney-classification:

- Comparable grading of Helicobacter gastritis:
 - very coarse criteria:
 - intestinal metaplasia (Grades 0,1,2,3)
 - atrophy (Grades 0,1,2,3) [not applicable in our studies]
 - coarse criteria:
 - chronic inflammation (Grades 0,1,2,3)
 - activity of inflammation (Grades 0,1,2,3)
 - fine criteria:
 - Helicobacter colonization (Grades 0,1,2,3)



Do we need focusing for the correct diagnosis?

Am J Clin Pathol 2008;130:259-264

Virtual 3D Microscopy Using Multiplane Whole Slide Images in Diagnostic Pathology

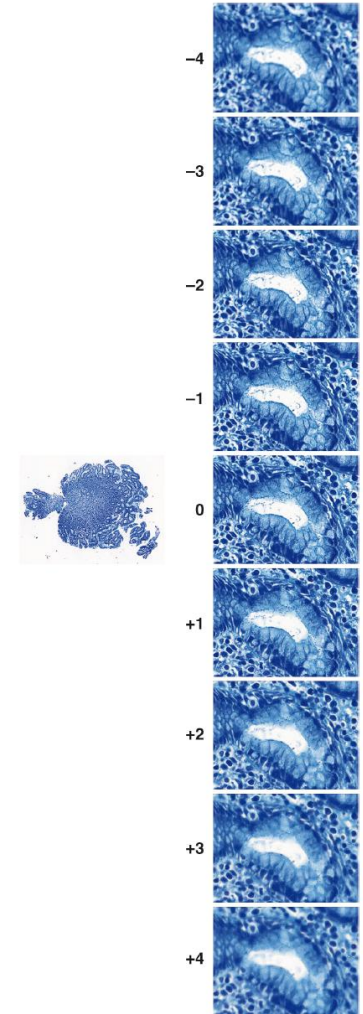
Thomas Kalinski, MD,¹ Ralf Zwönitzer,² Saadettin Sel, MD,¹ Matthias Evert, MD,^{1,3}
Thomas Guenther, MD,¹ Harald Hofmann,⁴ Johannes Bernarding, MD,² and Albert Roessner, MD¹

Comparative Study No.1:

- 144 gastric biopsies with/without *Helicobacter gastritis*
- 3 consultant pathologists:
 - conventional microscopy versus:
 - 1. virtual 2D microscopy (single focus plane)
 - 2. virtual 3D microscopy (5 focus planes)
 - 3. virtual 3D microscopy (9 focus planes)
- Standard format: JPEG2000; Compression: 20:1

Results:

- Virtual 3D microscopy with 9 focus planes is required for the correct diagnosis of ‚fine‘ criteria such as *Helicobacter* colonization
[specificity/sensitivity: ≥ 0.95 ; kappa: 0.9]
- Virtual 2D microscopy is sufficient for ‚coarse‘ criteria



Compression in virtual 3D microscopy -- where is the limit?

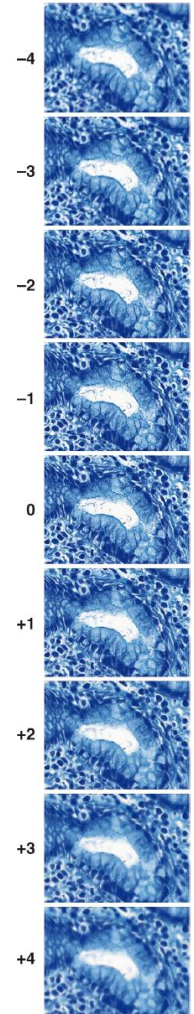
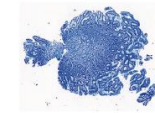
Human Pathology (2009) 40, 998–1005

Lossy compression in diagnostic virtual 3-dimensional microscopy—where is the limit?

Thomas Kalinski MD^{a,*}, Ralf Zwönitzer^b, Florian Grabellus MD^c,
Sien-Yi Sheu MD^c, Saadettin Sel MD^a, Harald Hofmann^d,
Johannes Bernarding MD^b, Albert Roessner MD^a

Comparative Study No.2:

- 46 gastric biopsies with/without Helicobacter gastritis
- 3 consultant pathologists:
 - conventional microscopy versus:
 - 1. virtual 3D microscopy (9 focus planes); Compression 20:1 (no visible artifacts)
 - 2. virtual 3D microscopy (9 focus planes); Compression 40:1
 - 3. virtual 3D microscopy (9 focus planes); Compression 50:1 (little artifacts)
 - 4. virtual 3D microscopy (9 focus planes); Compression 75:1
 - 5. virtual 3D microscopy (9 focus planes); Compression 200:1 (clearly visible artifacts)



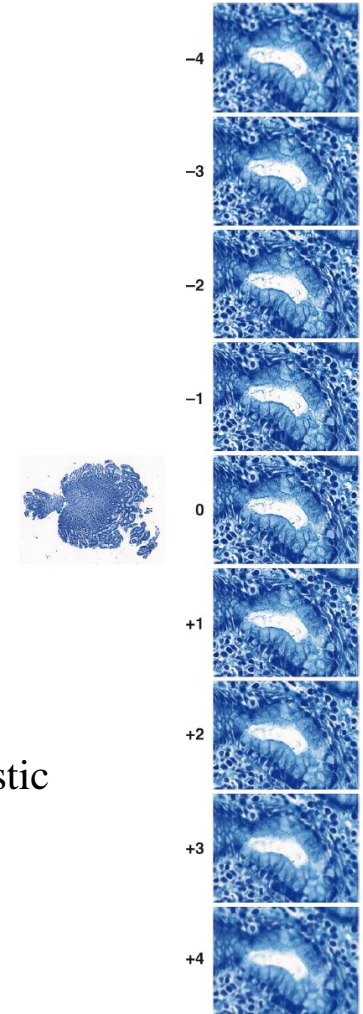
Results:

- Even high compression rates with clearly visible artifacts have little influence on the diagnostic accuracy in Helicobacter gastritis!

Can we really do without uncompressed virtual slide?

Comparative Study No.3:

- 46 gastric biopsies with/without Helicobacter gastritis
- 3 consultant pathologists:
 - conventional microscopy versus:
 - 1. virtual 3D microscopy (9 focus planes); Compression 1:1 (no compression)
 - 2. virtual 3D microscopy (9 focus planes); Compression 5:1
 - 3. virtual 3D microscopy (9 focus planes); Compression 10:1
 - 4. virtual 3D microscopy (9 focus planes); Compression 20:1



Results:

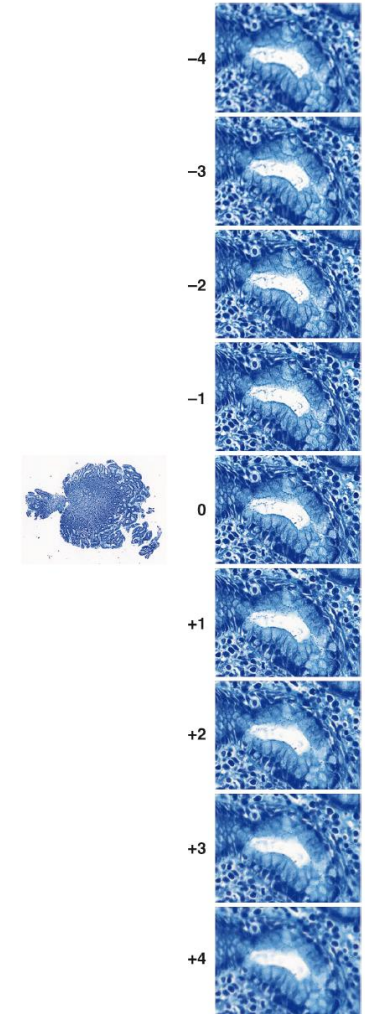
- Uncompressed or nearly uncompressed slides do not enhance the diagnostic accuracy!

What are the remaining questions?

Next comparative studies on lossy compression:

- Where is the limit in diagnostic virtual (2D/3D) microscopy regarding diverse diagnoses?
- Where is the limit in *image analysis*?

→ Towards a definition of the minimum image quality required in diagnostic virtual microscopy.



Thank you very much
for your attention.

