

---

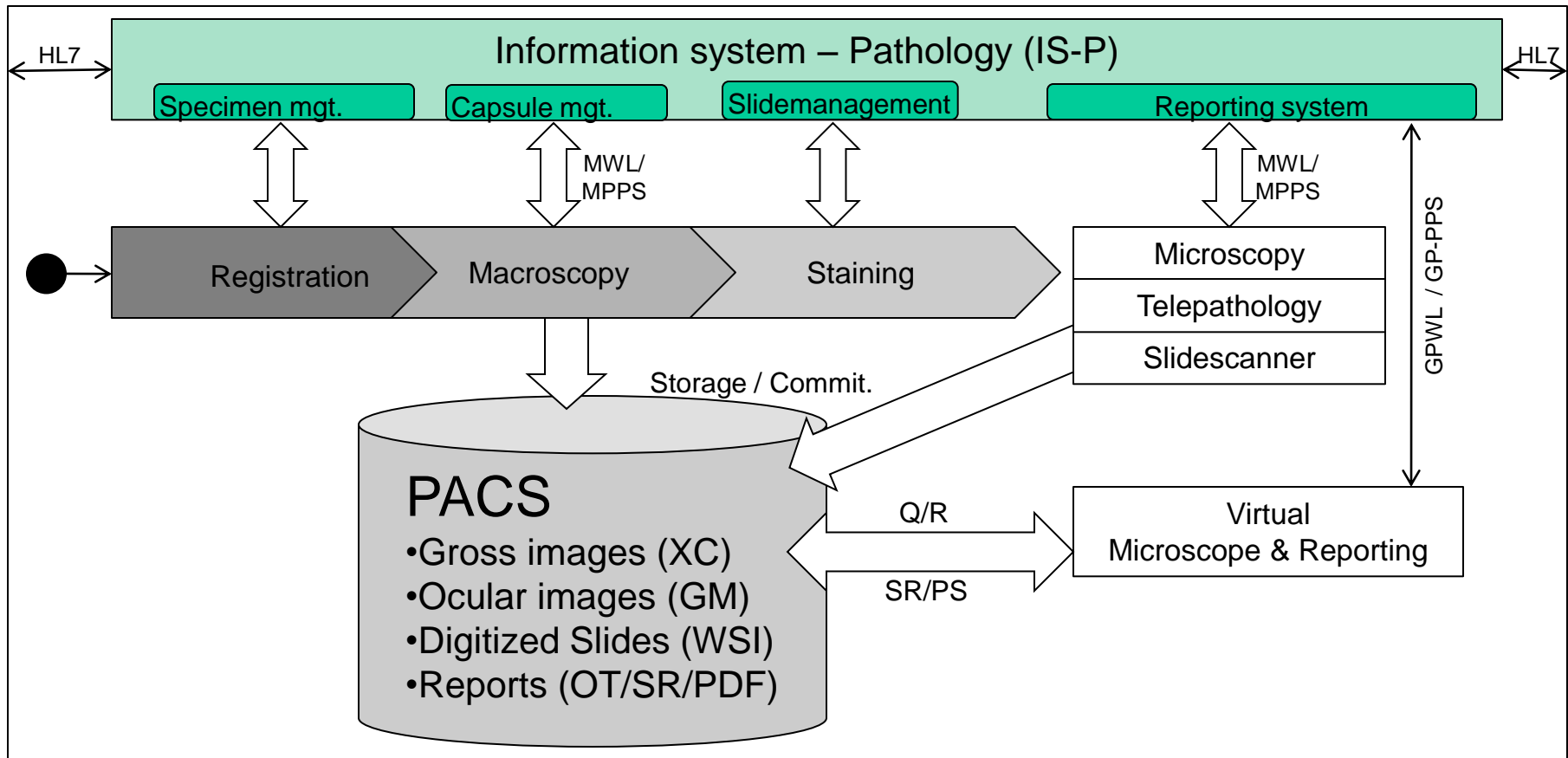
# DICOM-compatible compression of WSI and diagnostic evaluation

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.

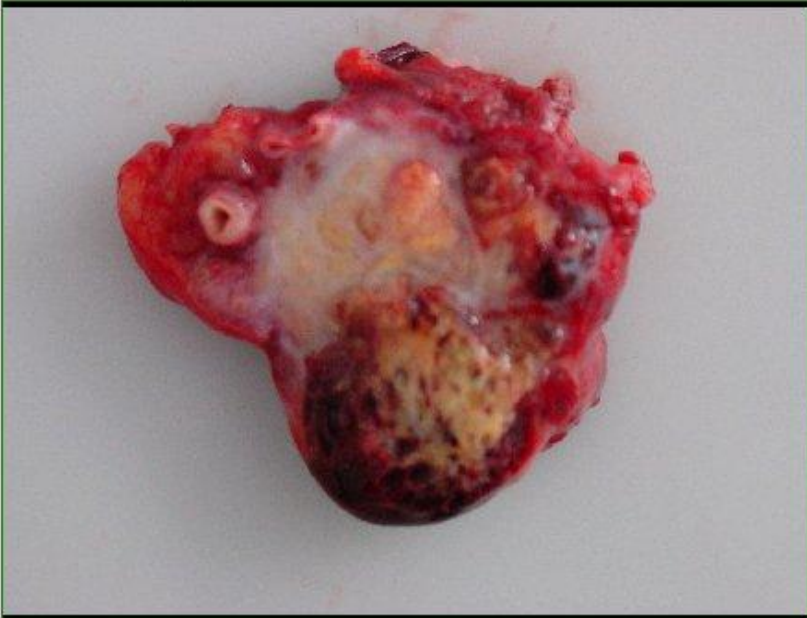
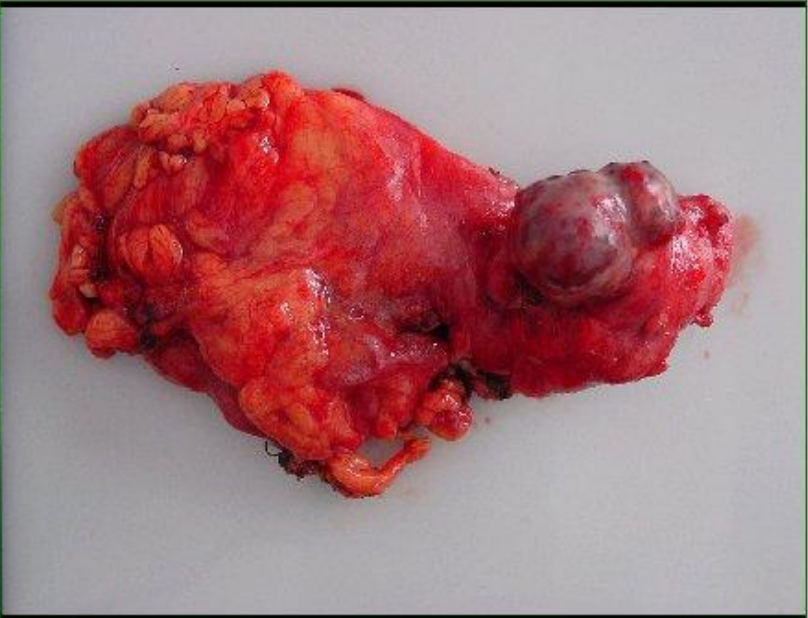
# Macroscopic Images (Clinic)

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'. The selected folder is 'Multiangel 16 Gradteile XC 17:16:31 (1) >Created<'. On the right, a table lists image files with their respective dimensions and storage information.

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, two side-by-side images show a specimen (a curved, yellowish object) inside a clear glass container. The images are presented in a multi-frame format, with the specimen appearing in different positions or orientations within the container.

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

# Microscopic Ocular Images

The screenshot shows a DICOM viewer interface. On the left, a tree view displays a folder structure under 'PATHO'. The selected folder is 'GM 17:15:23 (1) >Created<'. The main area shows a table of image data:

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 image thumbnails are displayed side-by-side. The left thumbnail shows a low-magnification view of a tissue section, while the right thumbnail shows a high-magnification view of individual cells with prominent nuclei.

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

# Whole Slide Images (WSI)

The screenshot displays a DICOM viewer interface. On the left, a file tree shows a hierarchy of folders and files, including 'PATHO', 'Routine Patient 02.01.1960 (RP1) >Created<', 'Direktor Karl Heinz Maelzer 12.11.1923 (KHM1) >Created<', '07.05.2009 WSI-Scan (RP12345) >Created<', 'WSI Schichtdicke ein Mü SM 17:14:10 (1) >Created<', 'WSI Schichtdicke ein Mü SM 18:22:08 (2) >Created<', and 'Ewis Lindemann Portner 02.05.1999 (EL1) >Created<'. The selected file is 'WSI Schichtdicke ein Mü SM 17:14:10 (1) >Created<'. On the right, a table lists the image metadata:

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 a thumbnail of the WSI on the left and a full-resolution view on the right. The thumbnail shows a dark background with some faint, illegible text and a small, light-colored area. The full-resolution view shows a histological slide with pink and purple staining, likely representing tissue sections.

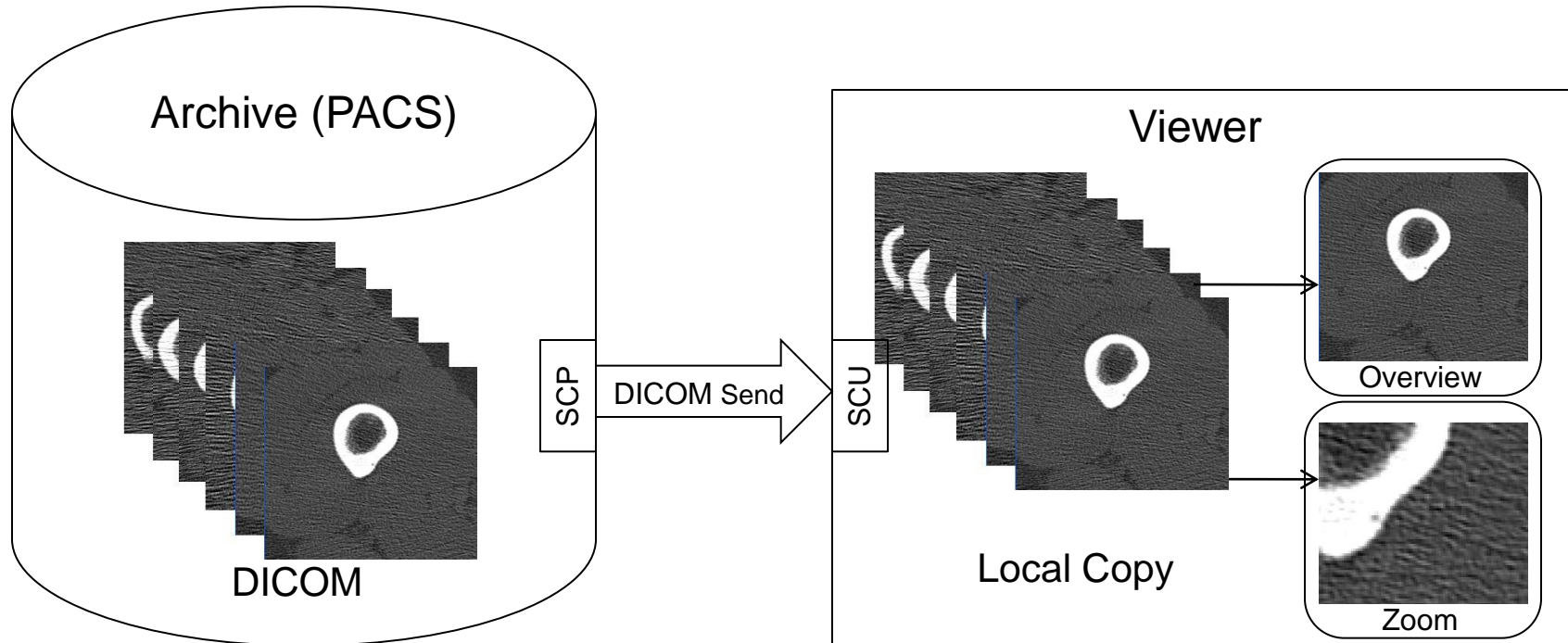
# Whole Slide Images (WSI)

The screenshot shows a DICOM viewer interface. On the left, a file explorer displays a directory structure under 'PATHO' with folders for 'Routine Patient 02.01.1960 (RP1) >Created<', 'Direktor Karl Heinz Maelzer 12.11.1923 (KHM1) >Created<', and '07.05.2009 WSI-Scan (RP12345) >Created<'. The selected folder is 'WSI Schichtdicke ein Mü SM 18:22:08 (2) >Created<'. The main window displays a histological slide with pink and purple staining. The 'Eigenschaften' (Properties) panel on the right shows the DICOM 3.0 Image metadata. The 'Class' is 1.2.840.10008.5.1.4.1.1.7 (Secondary Capture Image Storage). The 'IOD' is A.8.1 (SC Image) Mandatory. The 'Module' is C.7.6.3 (Image Pixel) Mandatory. The 'Entity' is Large Rows (UL) VM:1 VR:UL Superfluously by Condition ,n00280010 :. The 'Large Rows' (0510) and 'Large Cols' (0511) tags are circled in red, indicating their importance for WSI.

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

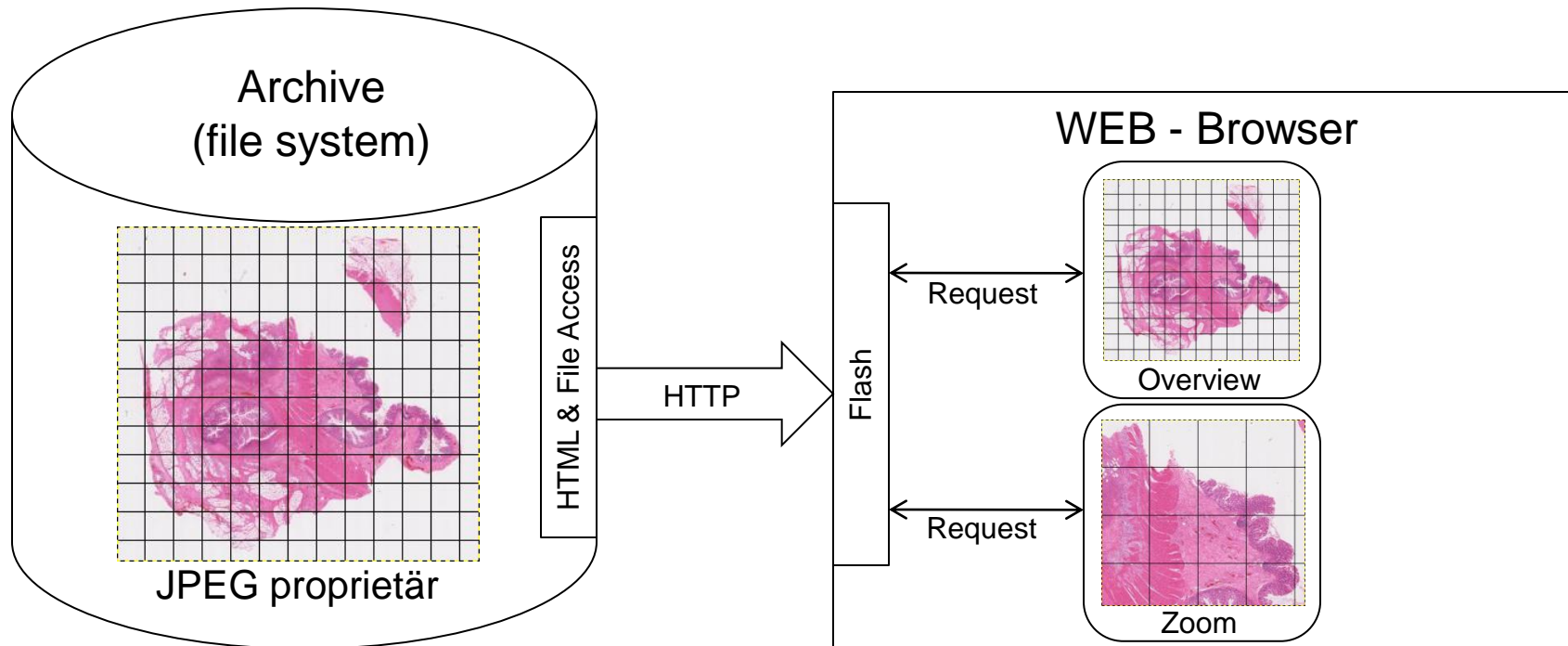


# Radiologic Image Distribution - DICOM (store and forward)



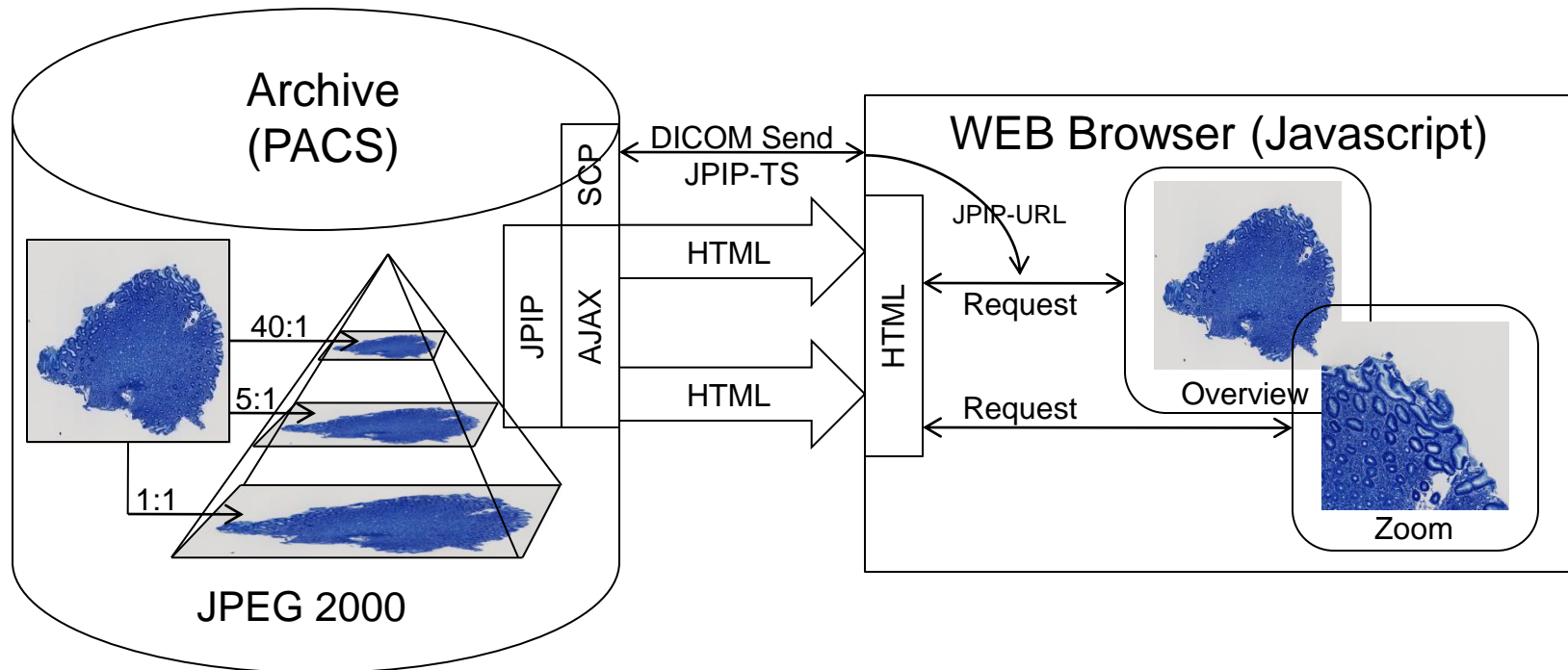
- Display after complete transport only
- Store and forward is not sufficient for very large WSI images
- Integration of JPIP in DICOM solves this problem by streaming

## 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.

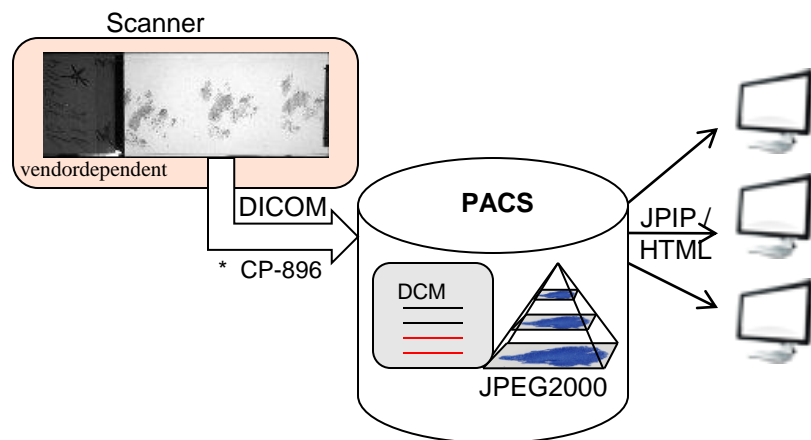
# Technical Requirements Image Compression

- 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

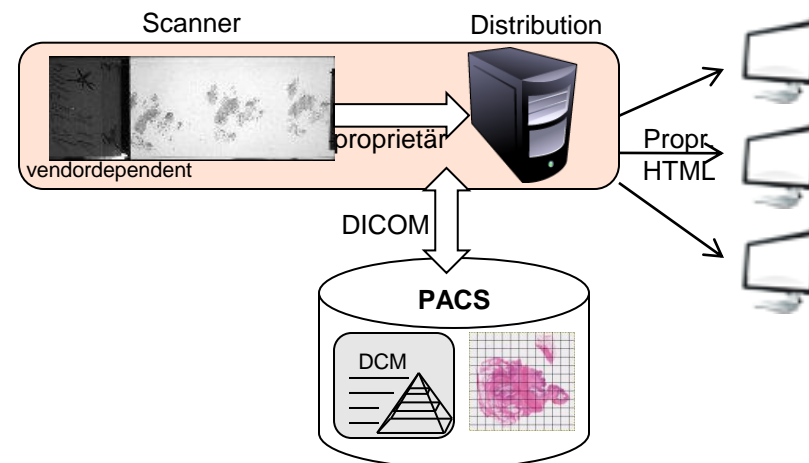
# Current WSI Approaches

## „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

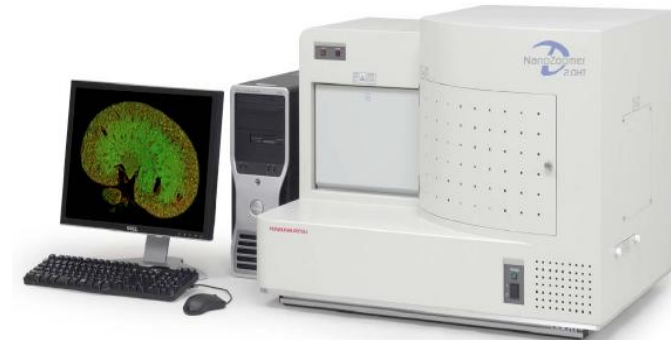
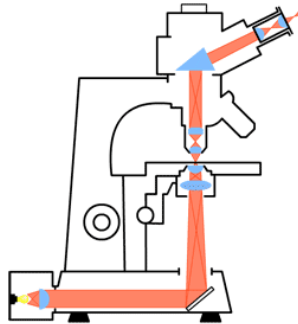


- Fractions instead of huge images
- DICOM Header contains progressive information
- Extra distribution needed
- Dependency on propr. distribution
- No synergy effects

## 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:

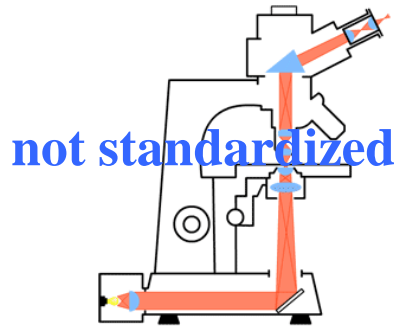
- Magnification
- Focusing
- Polarizing

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

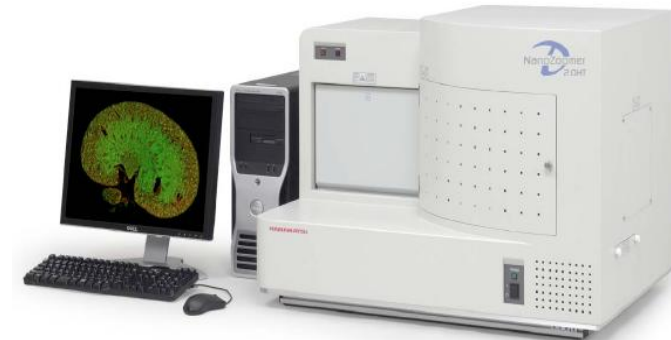
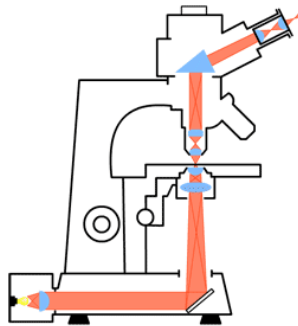
Scanner conditions (as provided):

- 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

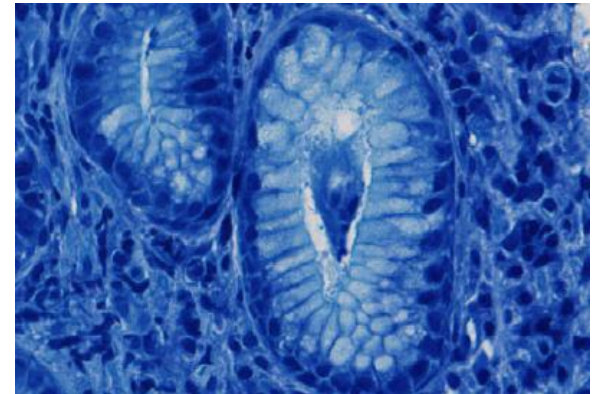


## To begin with... Helicobacter gastritis.



### 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

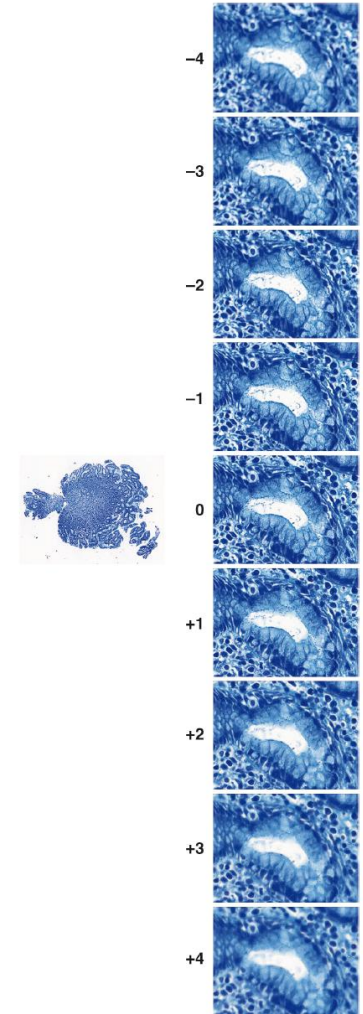
Thomas Kalinski, MD,<sup>1</sup> Ralf Zwönitzer,<sup>2</sup> Saadettin Sel, MD,<sup>1</sup> Matthias Evert, MD,<sup>1,3</sup>  
Thomas Guenther, MD,<sup>1</sup> Harald Hofmann,<sup>4</sup> Johannes Bernarding, MD,<sup>2</sup> and Albert Roessner, MD<sup>1</sup>

### 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:  $\geq 0.95$ ; kappa: 0.9]
- Virtual 2D microscopy is sufficient for ‚coarse‘ criteria



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

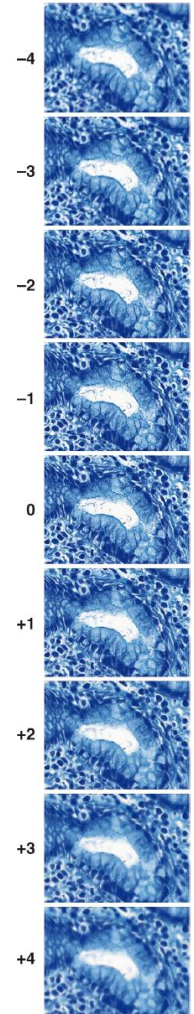
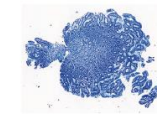
Human Pathology (2009) 40, 998–1005

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

Thomas Kalinski MD<sup>a,\*</sup>, Ralf Zwönitzer<sup>b</sup>, Florian Grabellus MD<sup>c</sup>,  
Sien-Yi Sheu MD<sup>c</sup>, Saadettin Sel MD<sup>a</sup>, Harald Hofmann<sup>d</sup>,  
Johannes Bernarding MD<sup>b</sup>, Albert Roessner MD<sup>a</sup>

## 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)



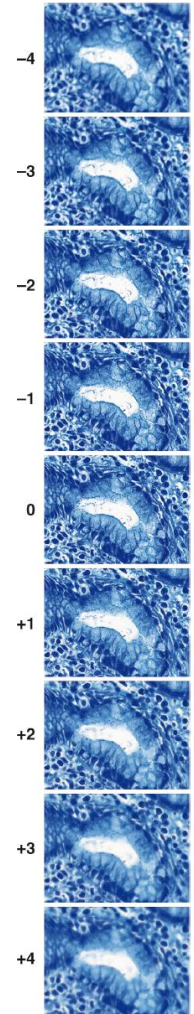
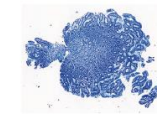
## Results:

- 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:

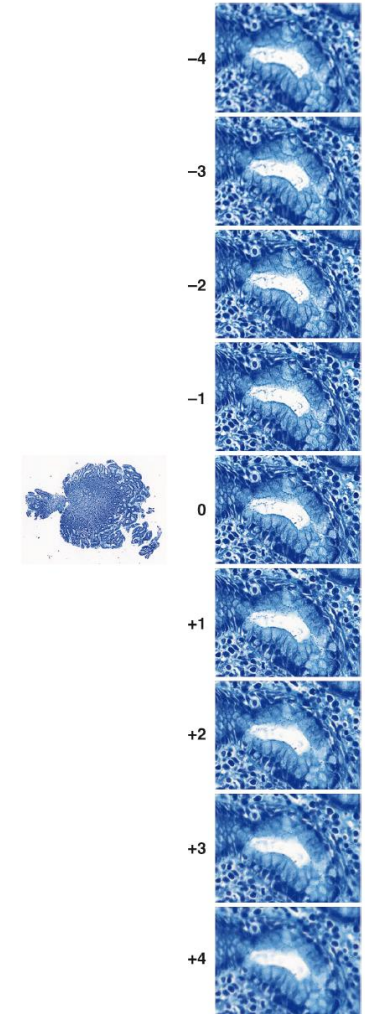
- Uncompressed or nearly uncompressed slides do not enhance the diagnostic accuracy!

# 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.

