Transferring the main features of a conventional microscope into the virtual domain using JPEG2000 technology

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Situation today

- The virtual microscope has been introduced in many areas but is lacking a broad acceptance in the clinical domain
- Reasoning is essentially based on the speed of the underlying processes from acquisition until availability of the image including the viewing process itself
- Where could JPEG2000's features yield improvements?

Weaknesses of whole slide imaging

- **Compression** during the **scan process** requires a speed-up to drop off the image data quickly and have the device available for scanning
- **Viewing** is still too slow and very often based on prefetching / caching especially if the image is stored remotely (standard strategy)
- Remote display of **focal planes** is an effort as well as their scan / compression and impairs the situation as a whole

Compression
- JPEG2000 Canvas -

- The JPEG2000 canvas is a reference grid where tiles can be located that divide an image into smaller rectangular regions
- Ideal for the task to compress tiles produced by the scanner and place them onto the canvas in the appropriate positions
- As the tiles are independent entities, the image can be viewed while the scanner and compression are still busy
- If the pixel data is not encoded consecutively (very often the case with WSI) the speed is increased (less pointer arithmetic)

Remote viewing
- JPIP -

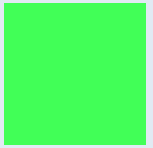
- JPEG2000's Interactive Protocol (JPIP) enables the retrieval of image regions (also tiles) that are requested by the viewer application by means of HTTP or TCP/IP in a compressed manner
- That way also low bandwidths (e. g. ADSL level) can be used to transfer the image data from central remote locations to the client
- In order to ensure good speed of viewing the client still requires at least moderate hardware (dual-core or better)

Focal planes
- multi-component transform -

- Creating n focal planes for WSI means to scan the image n times and get n separate images
- Comparable to tomography images in e. g. radiology that have a third dimension but with only slight changes in the third dimension for µm distances
- Idea: Use JPEG2000 to detect and compress those similarities

Focal planes
- multi-component transform -

2D: 5.000 x 5.000 px only green
file size after compression = 3 kB ⇨ similarities



- JPEG2000's concept of multi-component transforms extends the detection of similarities into the third dimension
- Efficiency of the compression and related bit rates is associated with the similarities between the different focal planes
- The approach must be valid for any image, independent of the distance and similarities

Focal planes
- multi-component transform -

- **3D**:
  - Example (1): 8 raw images each 4.096 x 3.072, 36.8 MB, 2 µm distance
  - Example (2): 8 raw images each 34.816 x 35.072, 3.58 GB, 1 µm distance

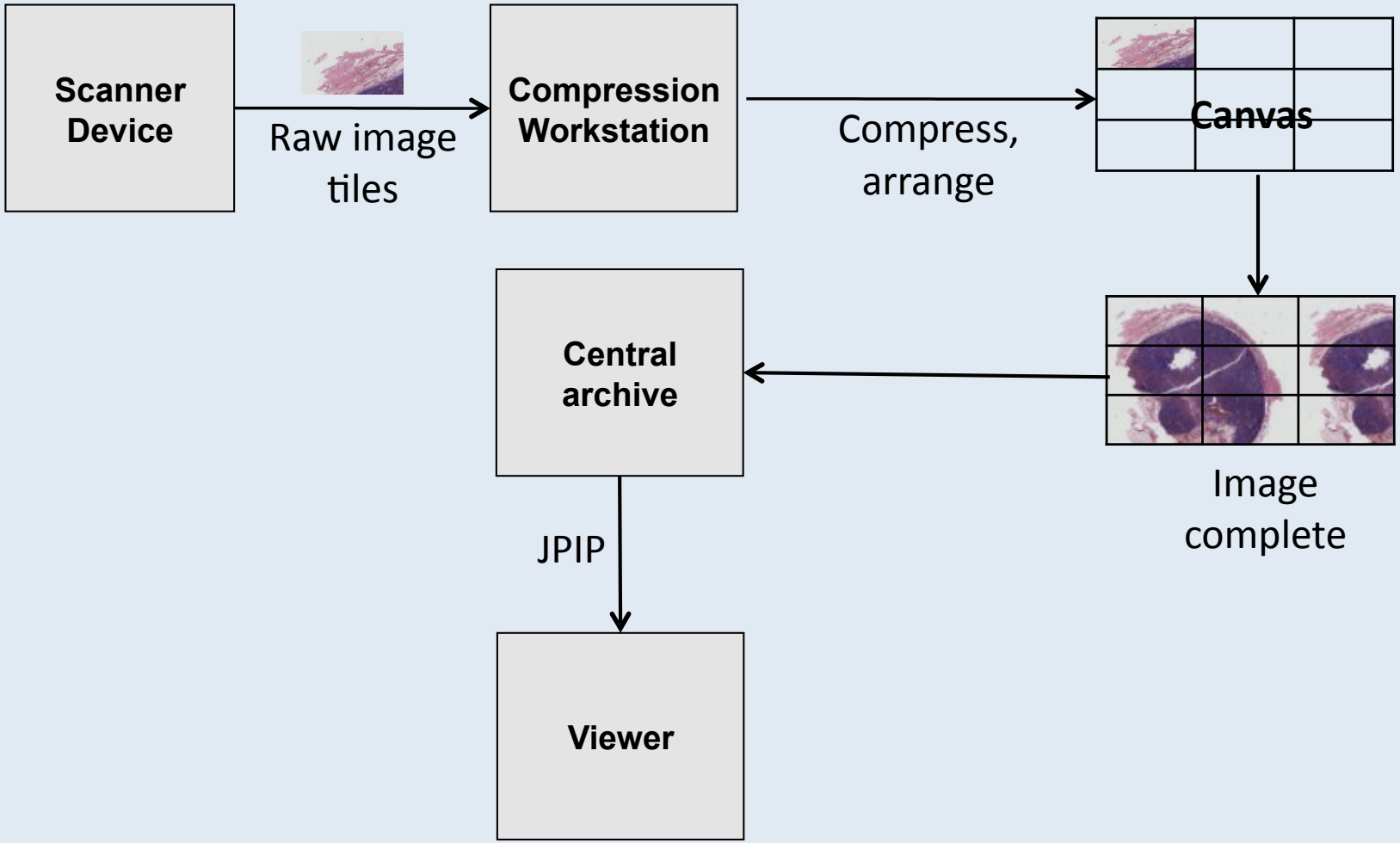
Image number	Example (1) File size, Time, Ratio*			Example (2) File size, Time, Ratio*		
1	1.584	2s	1:23	153.635	2:50min	1:23
1-2	1.939	4s	1:37	187.911	6:37min	1:38
1-4	3.262	8s	1:45	316.306	12:01min	1:45
1-8	6.524	15s	1:45	632.640	24:44min	1:45

(*) Measured on quad-core machine at 2.3 GHz, no visual loss

Focal planes
- multi-component transform -

- The elapsed time for the compression of all focal planes is proportional to the number of focal planes
- Single image with 6GB of raw data requires between 2:00 and 2:20 depending on hardware and image complexity
- No additional main memory is required for the focal planes to be encoded
- The compression efficiency for focal planes varies depending on the distance between the layers and the overall distance from the first until the last one, for 10 layers typically around 50-60%, topping out at about 85%

Architecture



Result / Conclusion

- The combination of the JPEG2000 features empower many scenarios and enable a more efficient virtual microscope
- Due to high compression rates and the JPIP approach also z-stack images can be viewed in real-time remotely, which makes it very efficient
- The “bottle neck” remains with the compression part and can only be accelerated by hardware improvements