Hybrid parallelization of a seeded region growing segmentation of brain images for a GPU cluster

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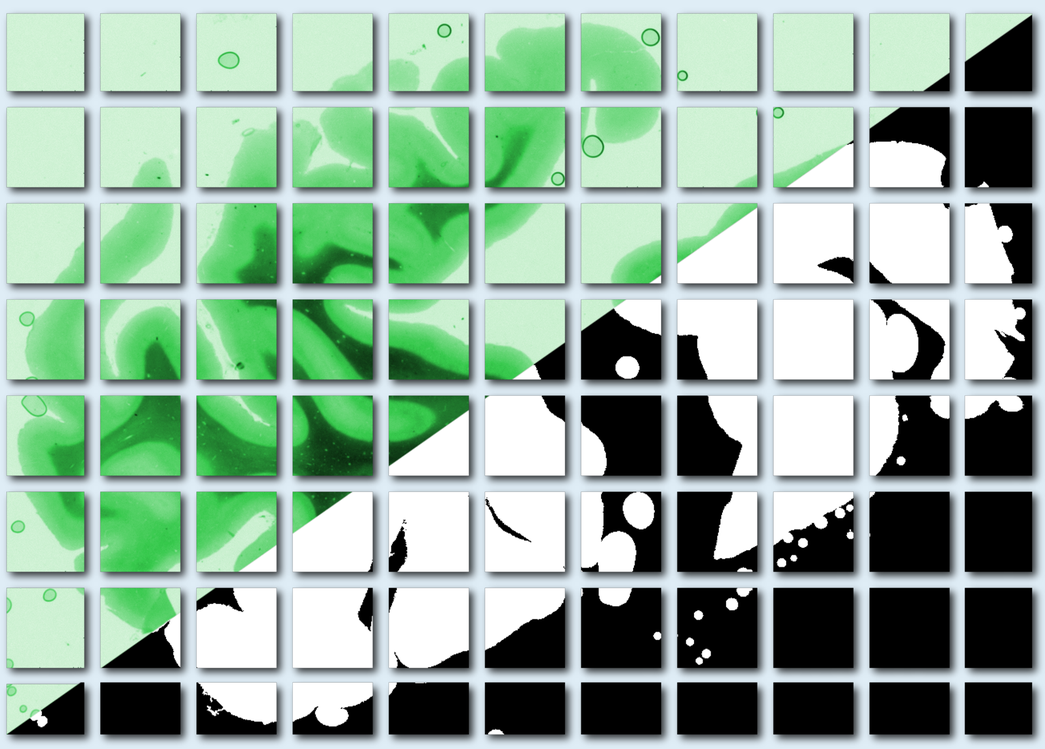


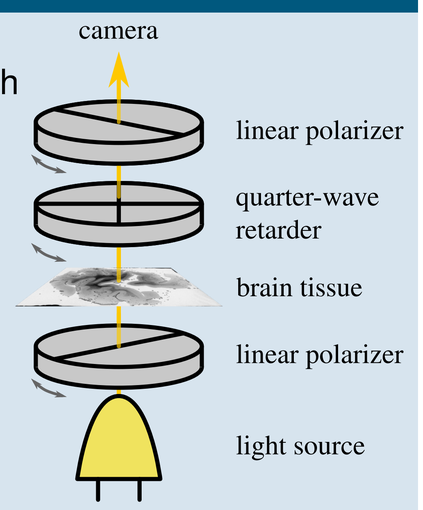
The introduction of novel technologies always carries new challenges regarding the processing of data.

- Newly developed imaging technique: Polarized Light Imaging
- Reconstructing hundreds of terabytes of image data
- Image segmentation as a preprocessing step: masking of brain and non-brain regions
- Parallelization of the segmentation for a GPU cluster

Polarized Light Imaging

- Development at the Institute for Neuroscience and Medicine (INM-1), Forschungszentrum Jülich
- Aim: extracting the course of single nerve fibers
- Sections of postmortem human brain tissue, each 70μm thick
- Imaging of the sections under linearly polarized light with varying polarization

1500	sections per brain
30×25	tiles per section
500	MB per tile
$1500 \cdot 750 \cdot 500\text{MB} \approx 500\text{TB}$	per brain

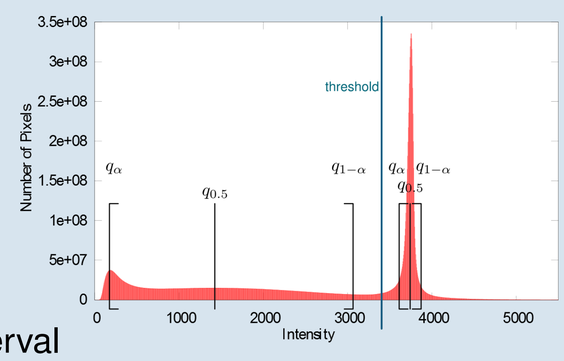


Automated Choice of Seeds

- Brain tissue on a bright background
- Including artifacts and image noise

1 **Joint intensity histogram** of all tiles

2 **Threshold** between brain and background intensities defined by user
→ single point of interaction per brain



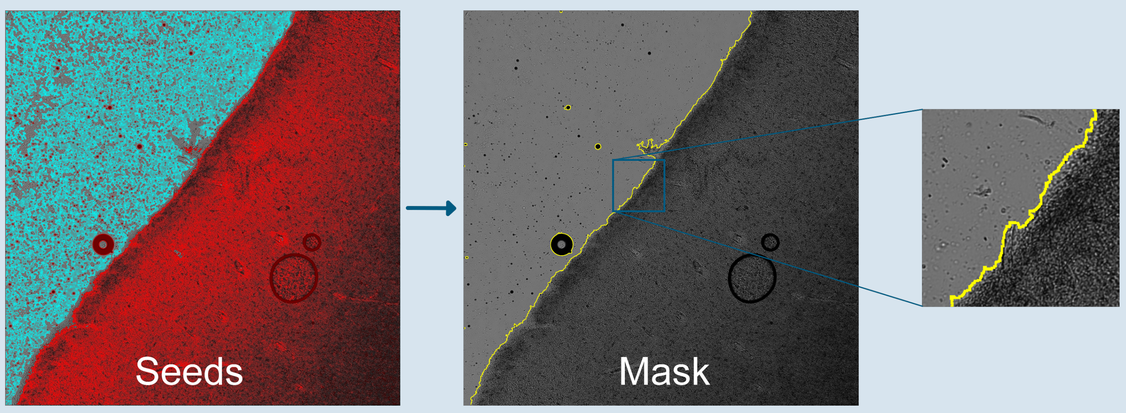
3 **Measure** m_{cand} for every intensity interval

$$m_{cand}(x,y) = \max\left(\frac{g(x,y) - q_{0.5}}{q_{0.5} - q_\alpha}, \frac{q_{0.5} - g(x,y)}{q_{1-\alpha} - q_{0.5}}\right)$$

4 **Linear smoothing** of m_{cand} to minimize the influence of image noise

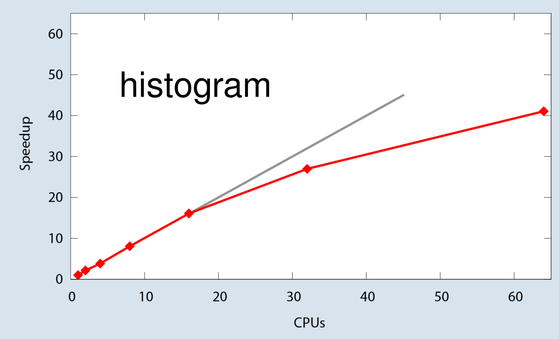
$$m_{final}(x,y) = \sum_{i=-m}^{m} \sum_{k=-n}^{n} w(i,k) \cdot m_{cand}(x+i, y+k)$$

5 **Removing dirt particles in the background marked as seeds**

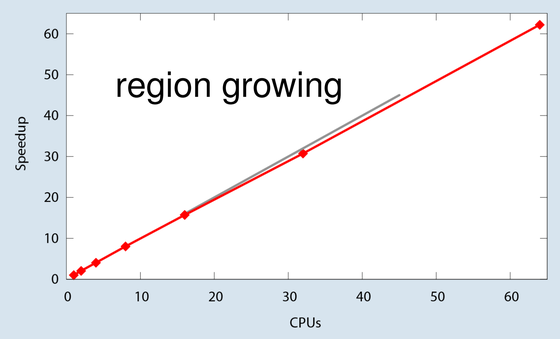


Multi-Core Parallelization

- Neighboring tiles: overlapping of $\sim 30\% \rightarrow$ independent processing
- Tiles equally distributed between the processes



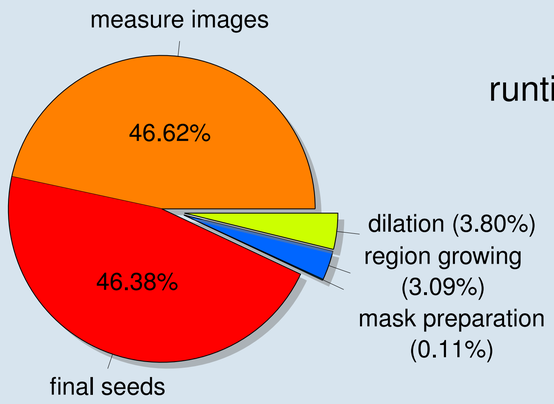
Single inter-process communication (`MPI_ALL_REDUCE`)



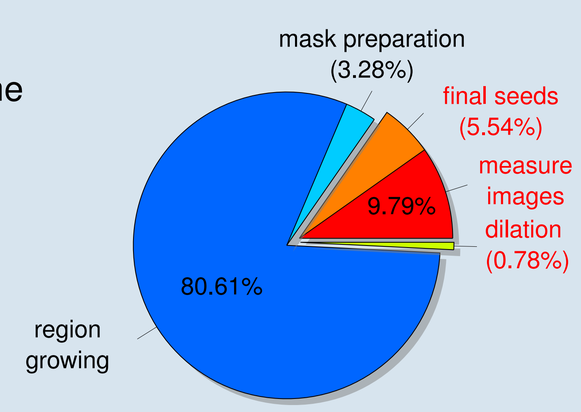
No communication required → **linear speedup**

GPU Parallelization

- Automated choice of seeds consists of data parallel steps
- GPUs take advantage of data parallelism → CUDA
- One-to-one assignment of pixels to CUDA threads



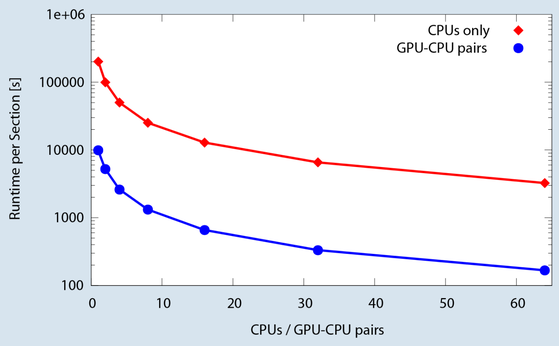
runtime



All steps executed on a CPU

These steps are CUDA parallelized

- Additional GPU accelerates the segmentation by a **factor of 20**



#CPUs	#GPUs	Runtime/Brain
1	0	**295 days**
1	1	15 days
64	0	4.6 days
64	64	**5.6 hours**