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CUDA defect detection in CT scans of tree trunks

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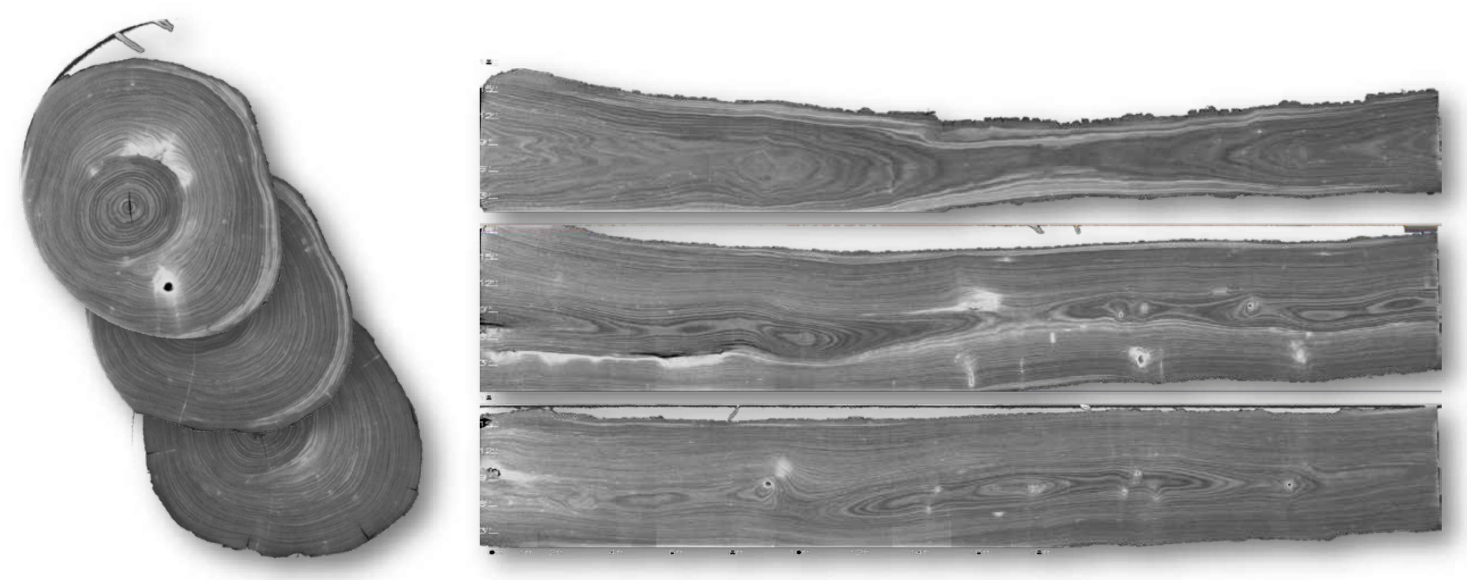
Motivation

In the wood industry, a difficult task is to **cut** the tree trunk (“**log**”) in a way to **maximize the yield** and quality of boards, as any **defects in the wood** (e.g. knots, cracks, decay) reduce the price of boards. This has been traditionally done by skilled mill operators who used their experiences to estimate where the defects could be located. Nowadays, we are able to look inside the log structure by using **CT scanners** and computerized analysis of the inner structure can significantly increase the yield and improve the quality of sawed boards.

However, processing the large scanned data can be **time consuming**. Since the requirement of the sawmills is to process scanned data in **real-time**, we propose **CUDA-accelerated application** using computer vision techniques to process the scans, detecting most typical internal defects in the wood and examine various ways of cutting the log to optimize the yield. By running most of the algorithms on the GPU, we can process the whole log **in matter of seconds** and give the most optimal solution for maximum yield. We tested our system on 65 scanned logs from 6 different tree species.

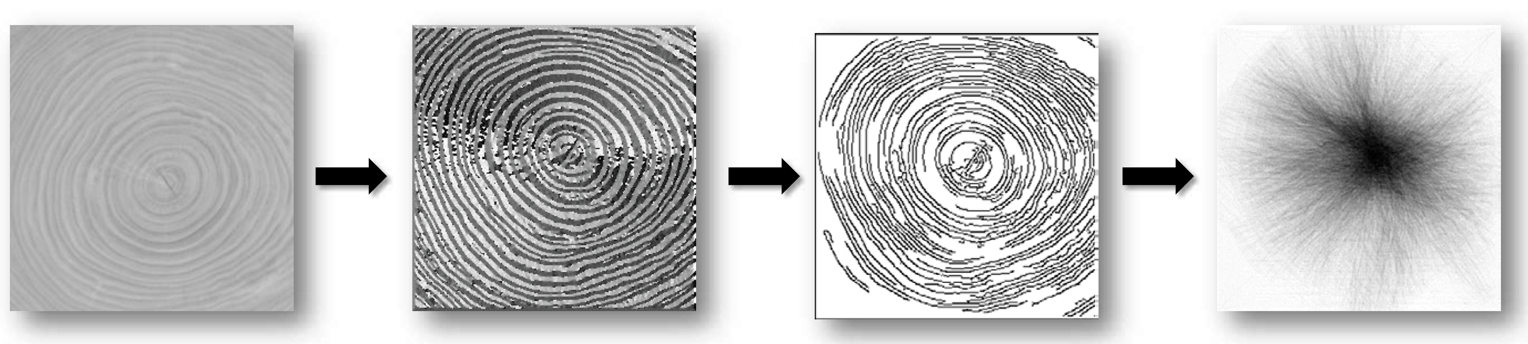
Industrial CT scanner (image courtesy of MiCROTEC)

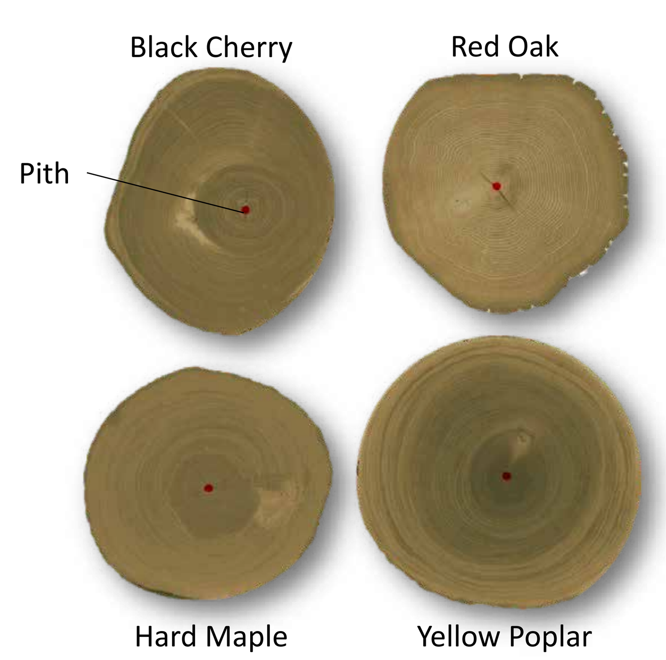


Raw output from the scanner (B&W image slices). Note the regular ring structure and defects

Data pre-processing

Data from the scanner are **volumetric** and are stored as B&W image sequence where each pixel represents wood density. Depending on the log length and scanner resolution, up to 1000 image slices can be generated. To suppress the noise in image slices, blurring or rank-order filtering is performed. From filtered data, **histogram** is computed for each slice to determine density thresholds. These are used to perform basic **segmentation** of the data. Data below low density threshold will be considered as low density defects (e.g. cracks or decay) and data above higher threshold will be considered as high density defects (e.g. knots and moisture). The rest is normal wood. Pre-processing runs on the GPU for all slices in parallel.

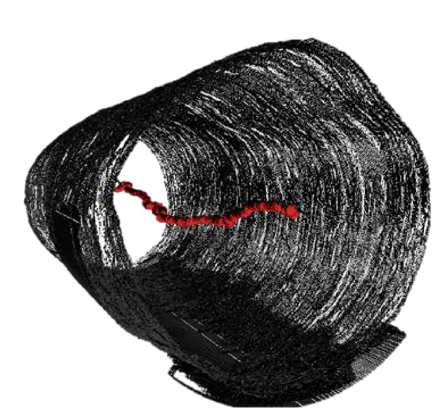




Finding the center of the log

Knowing the center of the log (**pith**) where growth rings start is crucial in detection of other defects. Since the pith position is rarely in geometric center of the log, it can also help to estimate ring eccentricity and how uneven was the growth of the tree.

Pith is computed with the use of modified **Hough Transform**. In each slice, edges and gradients are extracted using **Canny edge detector**. From every edge pixel, lines are drawn into the accumulator in the direction of the ring gradient. **Parallel reduction** is then used to find the maximum in the accumulator, marking the position of the growth rings center. This process is rather fast on the GPU and takes less than 5 seconds to process 1000 slices (on Quadro K4000) To test the results, we manually annotated pith on 22 logs from four wood species and compared to automatic detection. The mean error was less than 10mm that is sufficient for the detector.



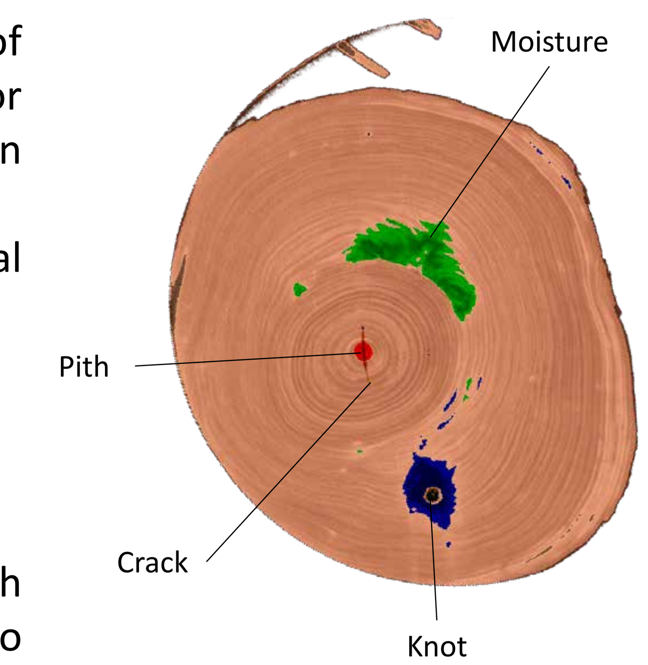
3D visualization of pith inside the log

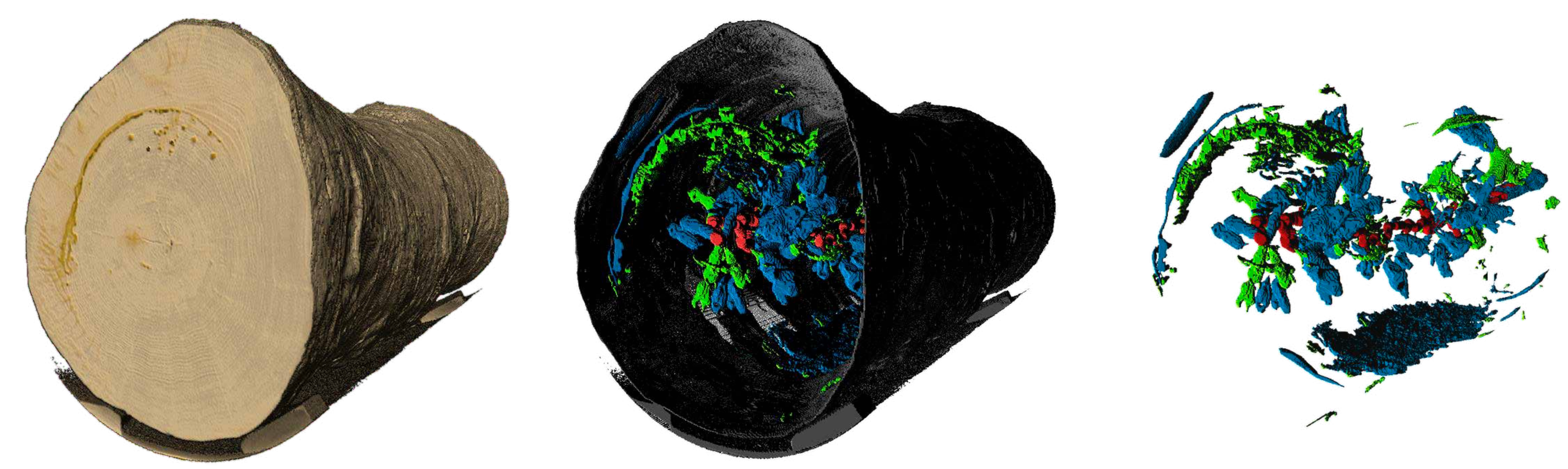
Defect detection and classification

Connected defect **regions** are isolated from the initial segmentation with use of seeding and **parallel clustering**. As each region is volumetric, it can be analyzed for slenderness and principal axes using principal component analysis (**PCA**). Based on these features coupled with density, we classify the regions into defect groups:

- **Knots**: long regions with high density (remainder of old branches) and principal axis having angle to pith in 30°-60° range
- **Cracks**: extremely thin and long regions with low density intersecting pith
- **Moisture**: high density, irregular shape (classified after knots)
- **Decay**: low density, irregular shape (classified after cracks)
- **Holes**: extremely low density, regular shape

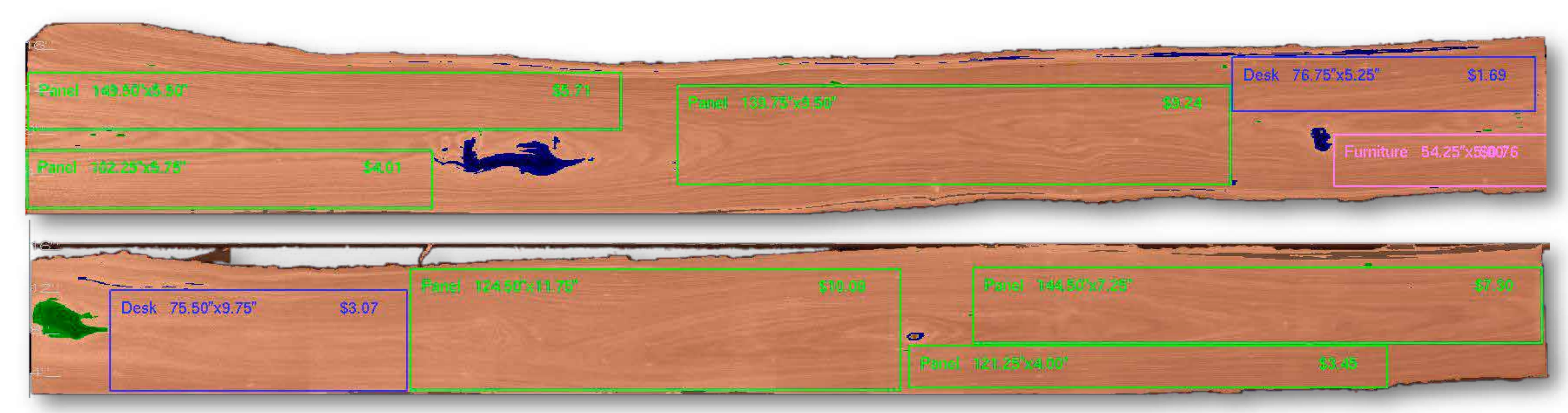
Coupled with pith detection, the analysis of the log contained from 1000 slice with 768x768 pixels per slice took less than **10 seconds on Quadro K4000**. We have also a CPU implementation, that with the same settings took almost **two minutes on Intel Core i7 920** (thus, the speedup is approximately 10x). Defects are visualized in 2D (in cross-sectional cuts of the log) or fully in 3D, using volumetric ray-casting. Each defect is visualized with different color.





Optimizations for sawmill and veneer process

After defects have been detected, **optimal cutting angle** of the log can be calculated. Each degree step is evaluated in parallel. The cut is analyzed in the means of how many boards can be created and what will be their quality. An algorithm is used to find biggest regions without any defect, therefore **maximizing the board quality**. Based on the size and shape of created boards, **price** for each cut is evaluated. After all angles are evaluated, they are visualized on the wheel user can rotate and see yield of various cuts. This method can **increase yield significantly**, up to 20% when compared to sawing without knowledge of internal defects. The evaluation time takes around **10-15 seconds on Quadro K4000** and depends on how many defects have been detected in previous steps.



Visualization of boards placed in different cuts

ACKNOWLEDGMENTS

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