Analyses and speed optimization of CT-based microstructure determination for wood based panels

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ABSTRACT:
Using computed tomography in combination with image analyses has been shown to be a valid technique for determining the microstructure of selected derived timber products. It has turned out that the complexity of this suggested method increases significantly with the size of the used structuring elements in 2D as well as in 3D. Therefore, we analyzed our algorithm to identify and point out computational complex regions and to appraise those which are suitable for optimization. Following that findings we propose a method for matrix decomposition from literature and the parallelization of matrix operations using GPGPUs.

1 INTRODUCTION

Image analysis based on computed tomography (CT) data has been shown to be a valid method for the determination of the microstructure of selected derived timber products. Images from a 3D Sub-Micrometer CT and a combination of erosion and dilatation operations using arbitrary shaped structuring elements (SE) were used to derive the number of microstructures in classes equivalent to the size of the structuring elements (Fig. 1). In particular, this procedure is carried out to characterize the microstructure of wood based panels, in exacting of oriented strand board (OSB), particle-board (PB) and medium density fiberboard (MDF). The method also enables the differentiation between material and void and to calculate the volume fraction of these phases to finally ascertain the pore size distribution within the panels [1], [2], [3], [4], [5]. While evaluating the results obtained, it turned out that the complexity of the suggested method increases significantly with the size of the used structuring elements in 2D as well as in 3D [3], [6].

The aim of the present paper is to review our work on different possibilities for decreasing the execution time by using techniques of decomposition of structuring elements in combination with multi-core CPU and GPU programming, respectively.

2 MICROSTRUCTURE DETERMINATION

As been illustrated in Fig. 1, data acquired by a Sub-µ CT Scanner is first preprocessed by applying a wiener filter for image enhancement and a median threshold to convert grayscale images into a logical (binary) representation. The resulting slices are then morphologically opened using structuring elements turning microstructures of the size of the structuring element into void. After each iteration, the number of eliminated microstructures is counted resulting in the cumulative percentage of size classes at the end of the procedure. While for the 2D-version of the method only single slices are evaluated during each iteration, the 3D-version additionally utilizes neighboring slices according to the height of the structuring element [6].

3 COMPLEXITY CONSIDERATIONS

Using the direct prototype implementation of the method showed that processing time increased dramatically with the size of the used structuring elements. To reduce execution time, areas for possible parallelization and simplification had to be identified. Fig. 1 shows the discovered critical sections of the algorithm.

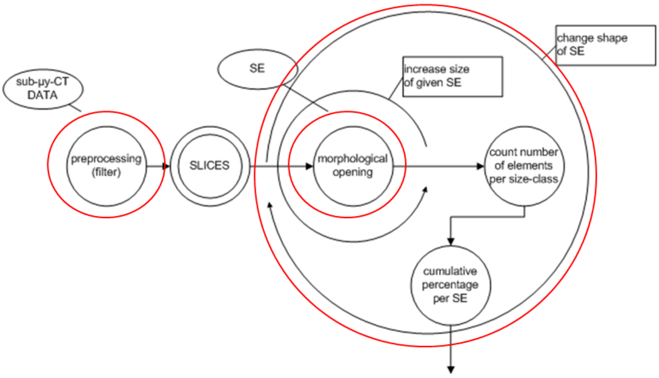

Figure 1. Critical sections of the method [3].

Preprocessing and iterations with differently shaped structuring elements can be easily done in parallel by processing more than one slice or structuring element, respectively, simultaneously. The morphological openings cannot be done at the same time as the result of the preceding iteration provides the input for a successive one. In the 3D-version additionally more than one slide is involved during each iteration. Due to that, paths to split the whole procedure had been elaborated and possible enhancements using different state of the art approaches for matrix decomposition and algorithms which promised to be independent of the size of a given structuring element had been itemized [3], [6]. Following those findings an algorithm, namely "Multi-level decomposition of Euclidean spheres" had been chosen and implemented and its performance, compared to the direct implementation has been measured. Results (see Fig. 2) had shown that the selected algorithm binds the time complexity of opening an image using an *n*-sized discshaped structuring element (SE). As it is available as a true 3D-version and can be applied to all 2D and 3D convex and symmetric structuring elements for any binary image data, further investigations were made on the possible speedup when using a GPGPU for the necessary matrix operations [3], [8].

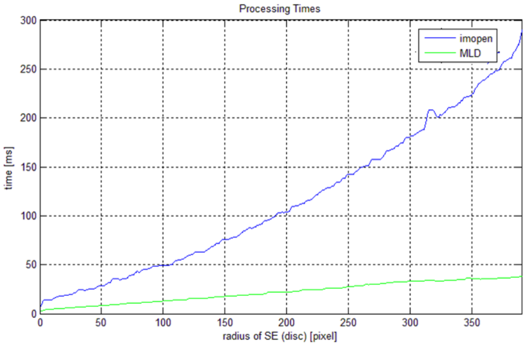

Figure 2. “Multi-level decomposition of Euclidean spheres” (slowly increasing, lower line) vs. direct implementation using Matlab [3].

4 MEASURMENTS

To explore the relative and absolute speedup when porting the matrix manipulation part (opening) of the method to a multicore CPU or GPU, measurements were performed on a dual Intel Xenon E5520 quadcore machine and on an Nvidia GeForce GTX 295 [7] using CUDA 3.1. To simplify matters, the Cartesian product of a random float vector with 32 elements and differently sized matrices were calculated. This is sufficient because we are interested in comparing the performance of single threaded, multithreaded and GPU matrix algorithms relative to each other. Figure 3 presents the mean results of the 10 measurements performed for each case.

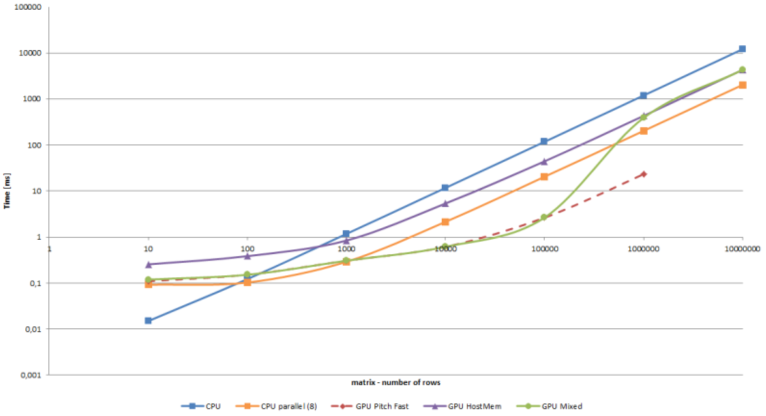

Figure 3. Comparison of different implementations of the Cartesian product. Both axes are logarithmic.

From Fig. 3, it can be seen that the multithreaded CPU implementation is about *n* times faster were *n* is the number of processors used. Only on small matrices the overhead of the thread library (posix) reduces that benefit. When using linear memory (pitched) on the GPU where the complete matrix is transferred to GPU memory before calculation, processing is faster up to 50 times than the multithreaded implementation. This approach is only limited by the memory available on the GPU. The version using host memory is not faster as the multicore implementation and the combination of pitched and host memory (mixed) provides an alternative if GPU memory is exceeded.

5 CONCLUSION

This article summarizes the computational complex parts of the proposed method for determination of microstructures in wood based panels. It explores different approaches to reduce processing time. In addition to proposing a method for matrix decomposition, measurements on parallelizing matrix operations on both multicore CPUs and GPGPUs were made.

REFERENCES

[1] Standfest, Gernot et al. (2009): Rohdichtebestimmung von Holzwerkstoffen mittels Computertomographie. In: European Journal of Wood and Wood Products, 67(1), S.83-87, Springer Berlin / Heidelberg.

[2] Standfest, Gernot; Kranzer, Simon; Petutschnigg, Alexander; Dunky Manfred (2010): Determination of the Microstructure of an Adhesive-Bonded Medium Density Fiberboard (MDF) using 3-D Sub-micrometer Computer Tomography. In: Journal of Adhesion Science and Technology 24 (2010), S. 1501-1514.

[3] Kranzer, Simon; Standfest, Gernot; Entacher, Karl (2010): Speed Optimization of CT-based Microstructure Determination using Matrix De-composition. In: Alfred Teischinger et al. (Eds.): Processing Technologies for the Forest and Biobased Products Industries, PTF BPI 2010, Salzburg, S. 36 – 41.

[4] Standfest, Gernot; Kranzer, Simon; Plank, B.; Petutschnigg, Alexander; Dunky, Manfred (2010): Anwendung der Sub-µm Computertomographie zur Charakterisierung von Holzwerkstoffen. In: Kastner (Hg.): Proceedings Industrielle Computertomographie Fachtagung. Zerstörungsfreie Bauteilprüfung, 3-D Materialcharakterisierung und Geometriebestimmung. 27.-29. September 2010: S 65–70.

[5] Standfest, Gernot; Kranzer, Simon; Salaberger, D.; Plank, B.; Petutschnigg, Alexander; Dunky, Manfred (2010): 3D Microstructure Characterization of Wood Based Panels. In: “Alfred Teischinger et al. (Eds.): Processing Technologies for the Forest and Biobased Products Industries, PTF BPI 2010. Salzburg, S. 96 -10.

[6] Kranzer, Simon (2010): Entwurf, Umsetzung und Evaluierung eines morphologischen Verfahrens zur Bestimmung der Porenverteilung in Holzwerkstoffen (Master‘s Thesis). Universität Salzburg, Salzburg/Austria.

[7] Kranzer, Simon; Unterweger, Andreas (2011): Performance Comparison of Vector and Matrix Manipulation Algorithms Implemented on Multicore Systems and GPGPUs (in preparation). Salzburg, Austria

[8] Vaz, Michael; Kiraly, A; Mersereau , Russel (2007): Multi-level decomposition of Euclidean speres. In: Proceedings of the 8th International Symposium on Mathematical Morphology. Rio de Janeiro, Brazil.