Shared-Memory Fast Marching Method for Re-Distancing on Hierarchical Meshes

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The fast marching method (FMM) is used in level-set based topography simulations to re-establish the signed-distance property of the level-set function, i.e., calculating the signed-distance to the zero-level-set. The signed-distance property is essential for numerically robust topography simulations. The typical geometries encountered when simulating feature-scale manufacturing processes of microelectronic devices consist of large flat regions and sharp corners which require a high spatial resolution. Considering that level-set solvers favor structured meshes because of efficient finite difference schemes, hierarchical meshes are inevitable to efficiently resolve small features in large simulation domains.

Hierarchical meshes naturally enable parallelism by allowing for independently executing the FMM on each mesh, followed by a synchronized exchange which then requires a partial restart of the FMM. However, the parallel speedup of this approach is often limited by the number and size of the given hierarchical meshes, especially for a high number of threads because of load imbalances. This bottleneck is overcome by a recent developed block decomposition approach, which allows for a higher parallel speedup [1]. The decomposition affects only the re-distancing, because the hierarchical meshes are already tailored to other computational tasks in the simulation flow, e.g., advection. To gain the best performance the block size and the stride width, i.e., the frequency of synchronization steps between meshes have to be tuned. Currently, the optimal decomposition size has to be determined on a case by case basis. To that end, we present an extensive parameter study, providing insights into the parameter selection.

Figure 1 shows the speedup of the re-distancing for the *Mandrel* geometry, measured on a single node of VSC-4. The *Mandrel* geometry consists of two trenches in an otherwise flat rectangular domain. By tweaking the stride width a serial speedup of up to 1.2 is possible. In case no decomposition is employed the peak speedup is 7.6 for 16 threads, however, using decomposition with a block size of 50 and stride width of 5.0 a speedup of 15.4 is achieved for 16 threads. In the decomposition case the speedup is further increased to 17.5 for 24 threads.

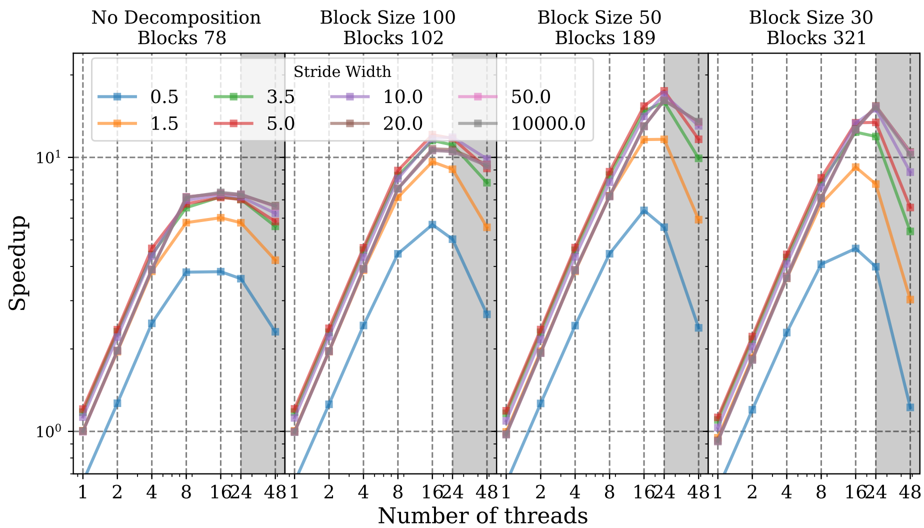

Fig. 1: Speedup of parallel re-distancing in dependence of block size and stride width. Reprinted with permission from [1]. Copyright 2021 Authors, licensed under the CCA 4.0 International License.

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References

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