Parallelizing the Particle Level Set Method

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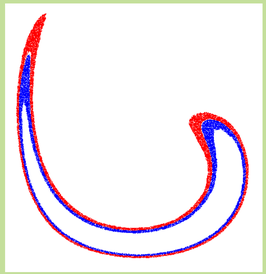
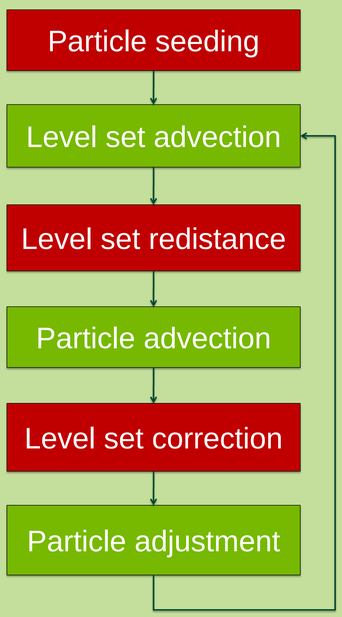
Introduction

The particle level set is widely used as an accurate interface tracking tool in simulation, computer vision and other related fields. However, high computation cost prevents applying this method to real-time and interactive scenarios.
This work intensively used parallel design patterns that are implemented in the thrust library, like compaction, reduction and scattering, to parallelize the particle level set method in order to attain real-time performance.



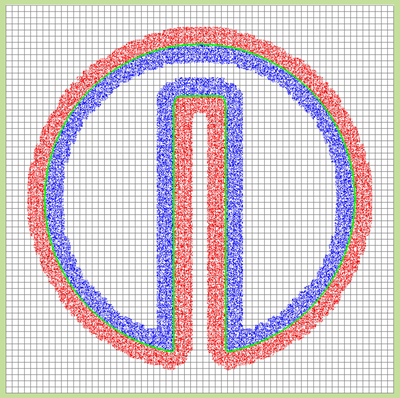
Outline

The flowchart shows the main steps of the particle level set method. The steps in red boxes are non-trivial to be parallelized, which will be discussed here in detail.

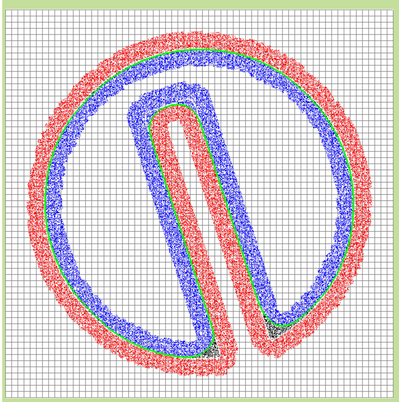


Particle seeding

- compact cell indices within the thickness of the interface
  thrust::remove_if
- randomly generate particle positions as in the Monte Carlo example (each cell has a unique seed)
- compact and remove those failed seeding
  thrust::remove_if



Level set correction

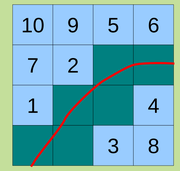


- Compact particle indices that indicate errors in the level set
  thrust::remove_if
- Duplicate each particles into 4 cells near it, and assign the cell indices as their keys
- Collect particles with the same key together
  thrust::sort_by_key
- Compute a correction value for each duplicated particle
- Attain the maximum correction value per each cell
  thrust::reduce_by_key

Level set redistance

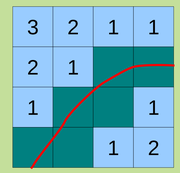
Serial Fast Marching

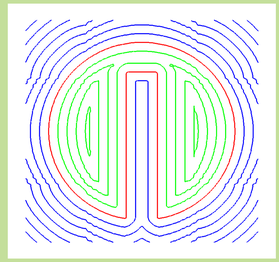
- advancing cell by cell
- ordering by heap sort: O(*n*lg*n*)



Parallel Fast Marching

- advancing ring by ring
- compact indices on the front
  thrust::remove_if
- parallel update of visiting tags
  thrust::scatter



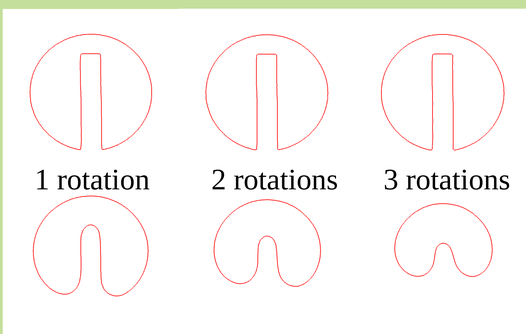


Less accurate than the serial version. But accuracy will be regained from particles.

Results

Single Vortex Test

A sphere deformed under a single vortex field into a thin shape and then recovered the original shape under the reverse field.



Comparison of Rigid Rotation Test

A notched disk rotates as a rigid body. The top row used the particle level set method; the bottom row used the pure level set method.

Timing Info

Resolution: 1024x1024

	Serial	Parallel
Fast Marching	128.621 ms/frame	9.214 ms/frame
Particle Correction	348.315 ms/frame	4.332 ms/frame