Parallelize 2D Optical Flow Estimation Algorithm on Video

Progress Report

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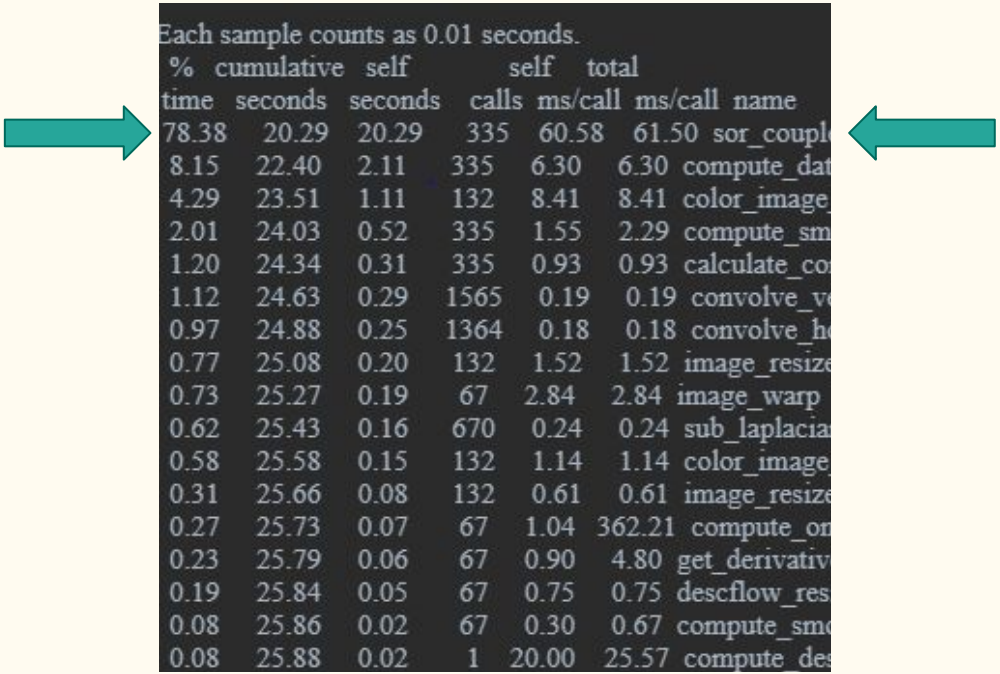
DeepFlow algorithm

- For a pair of consecutive images, deepflow algorithm minimizes a non-convex and non-linear energy function: downsampling first, fixed point iterations then and **iterative method** to solve linear equations.
- Iterative methods, such as Gauss-Seidel, Jacobi method, have a lot of matrix operations in every iteration, and that's where we can apply parallelism and optimizations.
- Existing codes use SOR to solve linear equations iteratively.

- SOR part takes over 78% of total running time.
- For each time the solver is called: the time complexity is $O(Mn^2)$

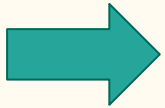


Each sample counts as 0.01 seconds.

% time	cumulative seconds	self seconds	calls	self ms/call	total ms/call	name
78.38	20.29	20.29	335	60.58	61.50	sor_coupl
8.15	22.40	2.11	335	6.30	6.30	compute_dat
4.29	23.51	1.11	132	8.41	8.41	color_image_
2.01	24.03	0.52	335	1.55	2.29	compute_sm
1.20	24.34	0.31	335	0.93	0.93	calculate_co
1.12	24.63	0.29	1565	0.19	0.19	convolve_v
0.97	24.88	0.25	1364	0.18	0.18	convolve_h
0.77	25.08	0.20	132	1.52	1.52	image_resize
0.73	25.27	0.19	67	2.84	2.84	image_warp
0.62	25.43	0.16	670	0.24	0.24	sub_laplacia
0.58	25.58	0.15	132	1.14	1.14	color_image_
0.31	25.66	0.08	132	0.61	0.61	image_resize
0.27	25.73	0.07	67	1.04	362.21	compute_or
0.23	25.79	0.06	67	0.90	4.80	get_derivativ
0.19	25.84	0.05	67	0.75	0.75	descflow_res
0.08	25.86	0.02	67	0.30	0.67	compute_smo
0.08	25.88	0.02	1	20.00	25.57	compute_des

Parallel Computing Structure

- **Big Data**: divide video into pairs of 2 consecutive images:
  - MapReduce: Task Level
- **Big Compute**: in solving linear systems part, instead of SOR (Successive over-relaxation), we apply other solvers (Jacobi, RedBlack SOR), where data dependency is less:
  - OpenMP+MPI: Loop Level
  - OpenACC: Loop Level



- We partition video into multiple pairs of images and run deepflow algorithm on all of them: **Data Parallelism**
- We do operations on matrices, and operation on each element is independent within each iteration: **Function Parallelism**

Parallel Model: **Multiple Program - Multiple Data**

Overheads, expected speed-up, future improvements

- **Overheads**
  - Communications
    - MapReduce: network latency
    - MPI
  - Synchronization
    - OpenACC
    - OpenMP+MPI
- **Speed-up:** for a pair of 720p images, on 2-core CPU,
  - 12s using Jacobi with OpenMP
  - 18s using SOR optimized for serial
  - 24s without any optimization
  - Expected near-linear speed-up
  - Strong scaling (total problem size fixed)
- **Next steps**
  - apply MapReduce to process video
  - Try MPI
  - replace Jacobi with RedBlack SOR to achieve better convergence