RANS CFD Solver on Fermi

Peng Wang, NVIDIA

On Behalf of

James Lin

HPC Center, Shanghai Jiao Tong University

GTC @San Jose, May 2012

Outline

- Related Work
- Background
- Design and Implementation
- Results analysis
- Conclusion and Future work

Related Work

Navier-Stokes Stanford University Solver(NSSUS)

15-20x Speedup On NVIDIA 8800GTX

Stanford

E.Elsen etc

2008.12

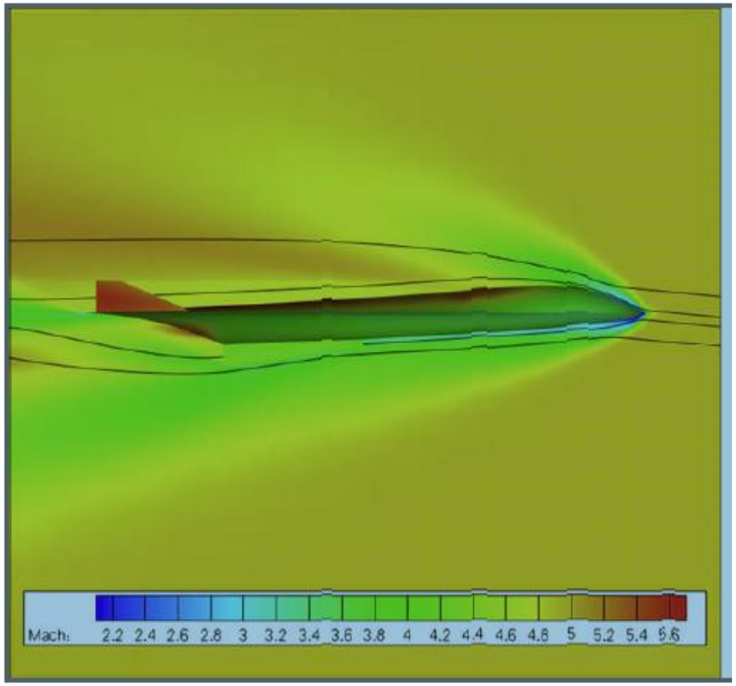


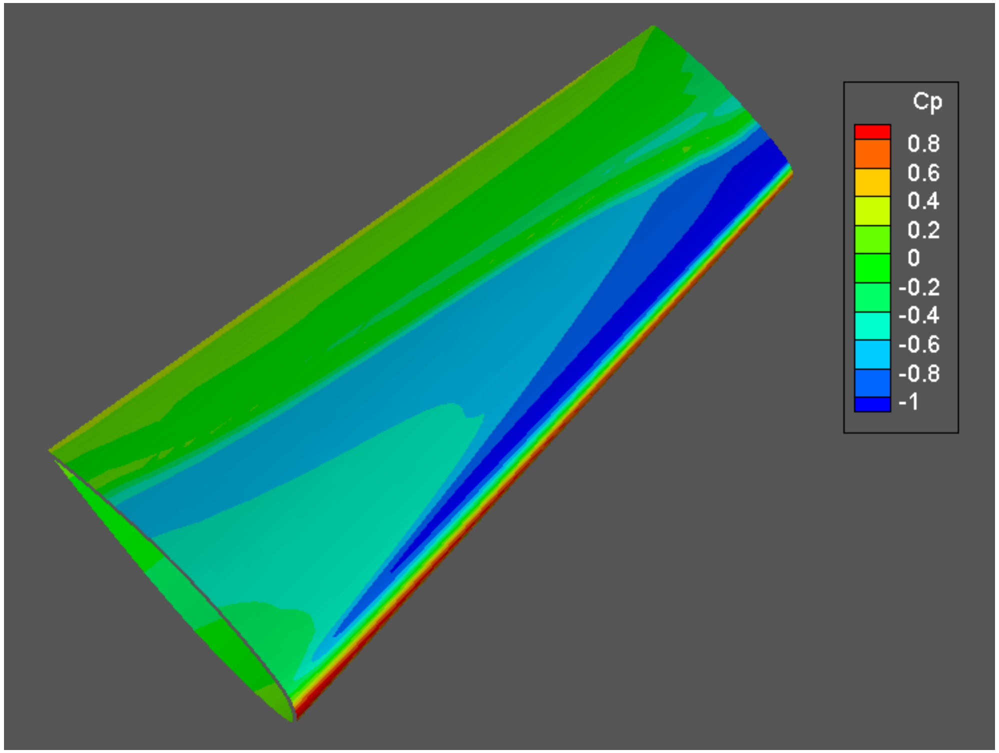
Table 2
Speed-ups for the hypersonic vehicle computation

Mesh size	Multi-grid cycle	Speed-up
720 k	Single grid	15.4
720 k	2 Grids	11.2
1.5 M	Single grid	20.2
1.5 M	2 Grids	15.8

Other Work

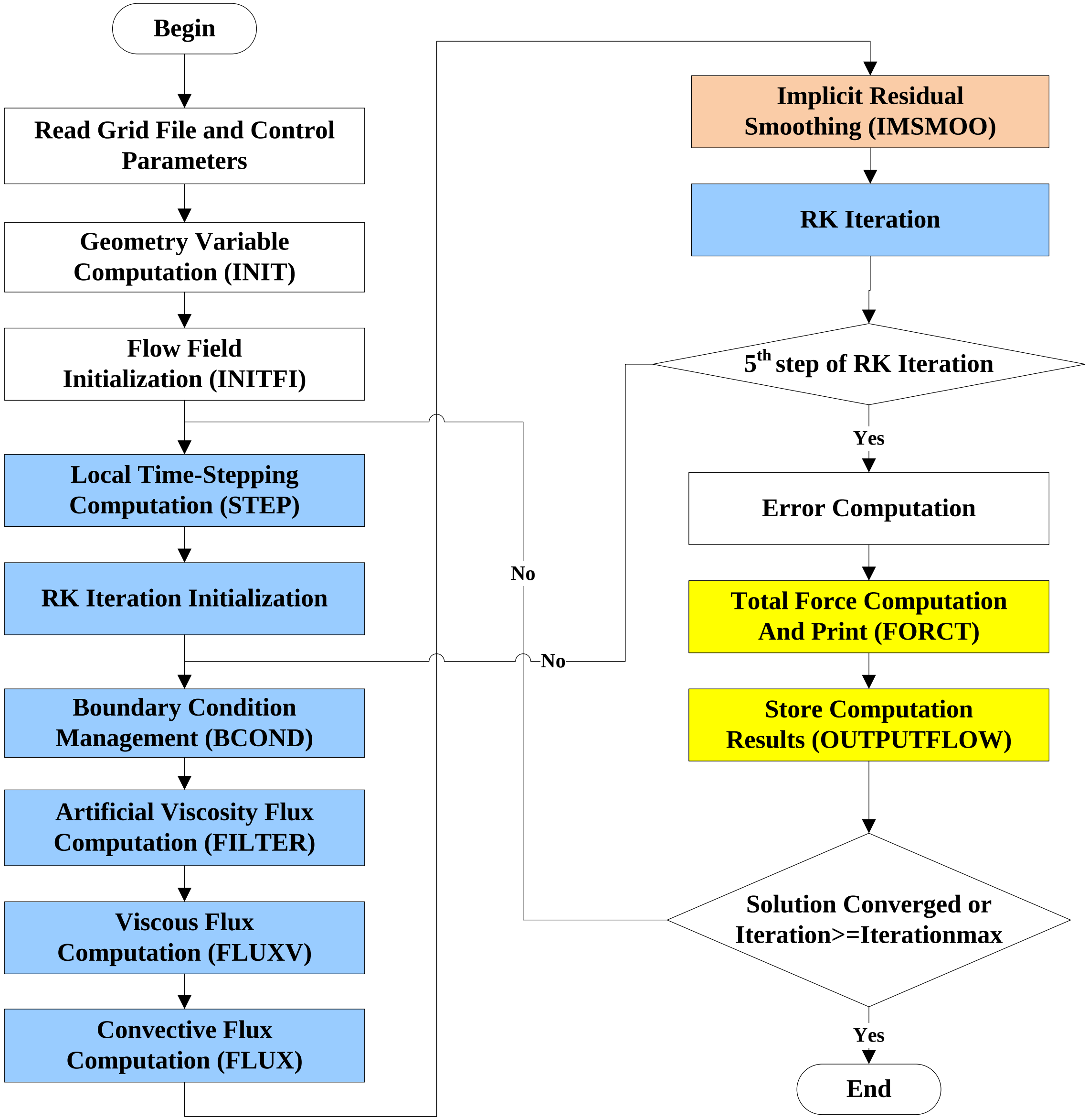
1. J. C. Thibault et al. implemented a Navier-Stokes(NS) Equation solver for incompressible flow on Tesla C870 boards, 13X on 1 GPU and 21X on 2 GPUs
2. Tobias Brandvik et al. ported Euler Equations onto GPU and a speedup of 29x in 2D and 16x in 3D
3. A. Corrigan et al. implemented 3D unstructured grid Euler solver for the inviscid compressible flow, and get 33x speedup on 1 C1060
4. I. C. Kampolis et al. use of the 2-D Euler solver for inviscid compressible flow to optimize the aerodynamic performance of the airfoil, get 15 X speedup with single precision and 21X with double on GTX 285

RANS Solver in SJTU

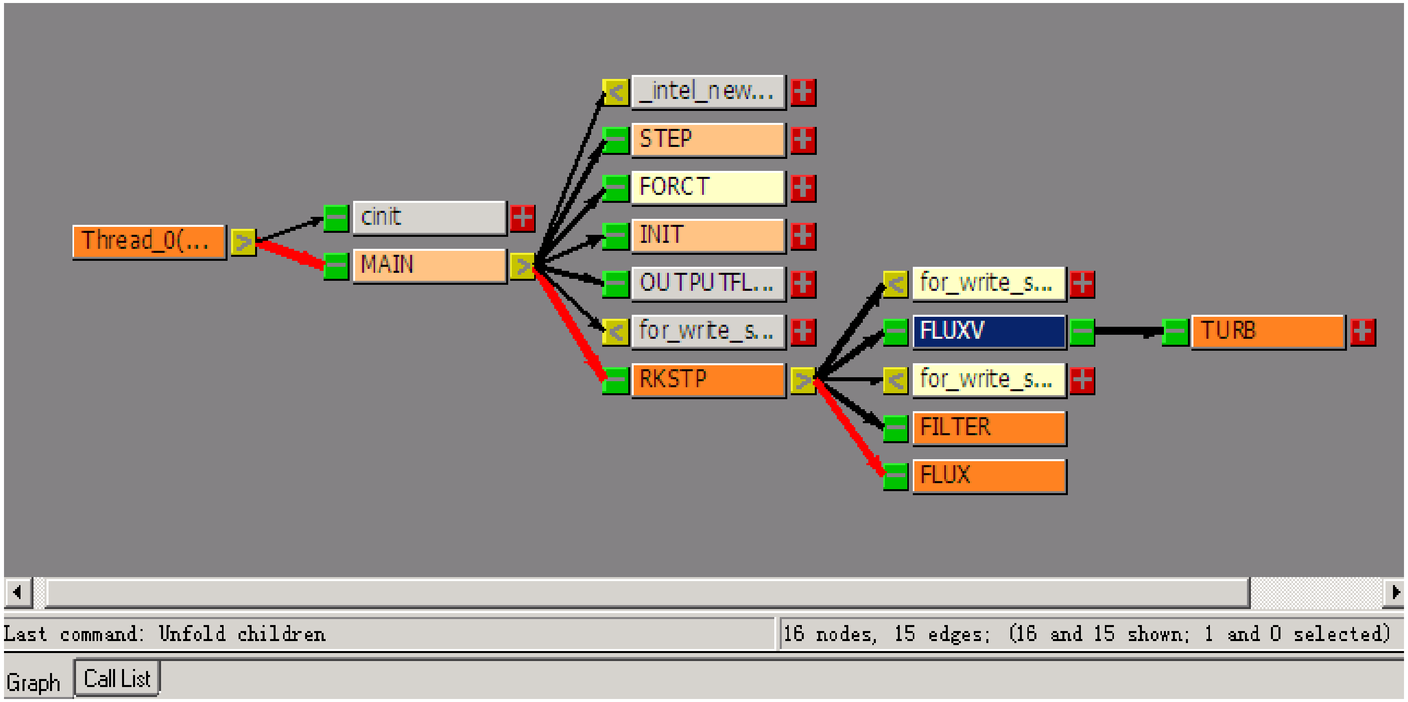


- CFD code by SJTU
- Used in COMAC
- Simu. For Wing design
- Based on RANS Equ.
- FVM on Struc. Grid

Flowchart of Sequential code



Finding hotspots of RANS Solver



Callee Function	Contribu...	Edge Time	Edge Calls
RKSTP	95.7%	37,332,081	50
FORCT	1.1%	415,573	11
STEP	1.1%	415,028	10
for_write_seq_li...	1.0%	384,860	232
OUTPUTFLOW	.4%	173,576	1
INIT	.2%	61,507	1

Callee Function	Contribu...	Edge Time	Edge Calls
FLUX	26.1%	9,726,010	250
FILTER	25.8%	9,616,121	100
FLUXV	23.[illegible]	8,709,589	50
BCOND	6.2%	2,302,139	250

Parallel Approach

- Aggregation

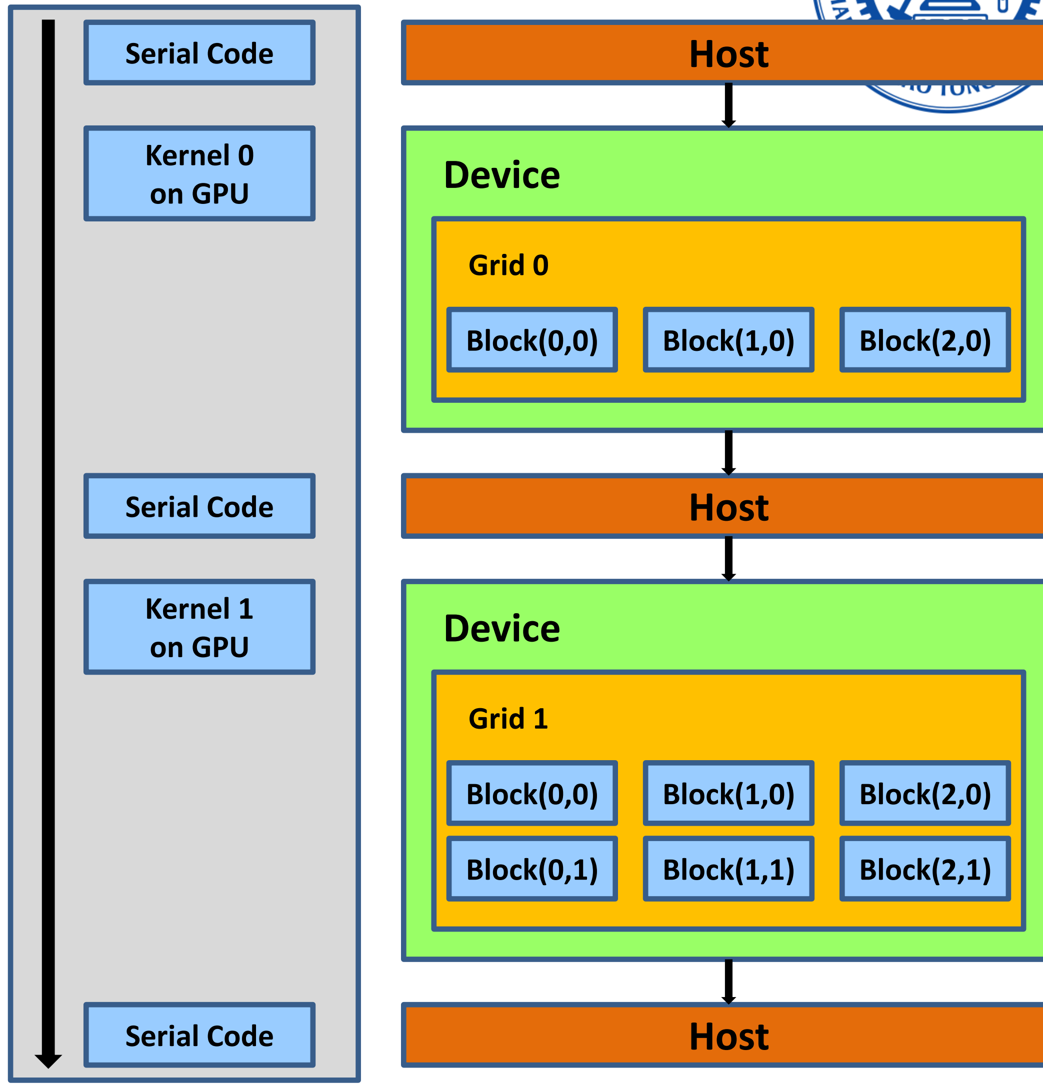
  Compute: Rk inter. + accer. Conv.

  IO ops: print and write file

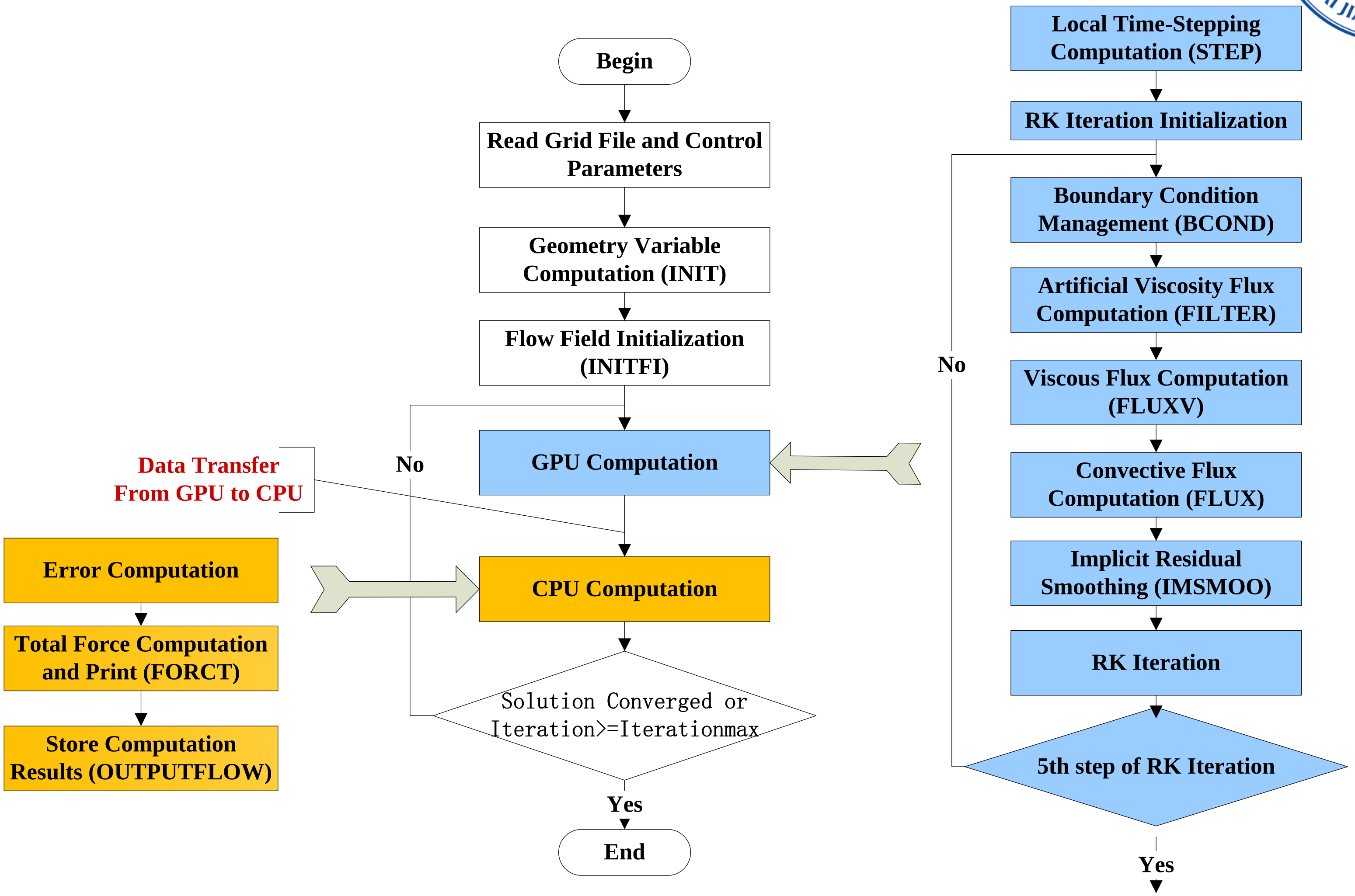
- Mapping

  Compute: → GPU

  IO ops: → CPU



CUDA version of Flowchart



Optimization Technique

- for better locality, transformed 1D matrices stored intermediate variables to 3D matrices
- to update data in neighbor vertexes, used multiple kernels to synchronize globally
- to eliminate data transfer between host and device memory, paralleled one direction each time in Implicit Residual Smoothing Algorithm
- for better access to global memory after matrices transformation: coalesce access.

Test Environment

Hardware

CPU：Intel(R) Core(TM) i7 CPU **920 @ 2.67GHz**，Quad-Core

Cache：32KB x 4 L1 Cache，256 x 4 L2 Cache，8 MB L3 Cache；

Memory：**6GB** DDR3，1033MHz；

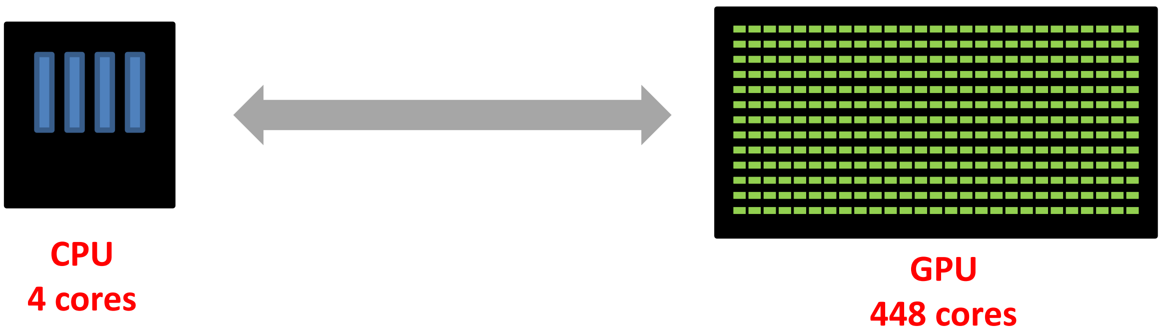
GPU：**Tesla C2050** with 2.78GB global memory，65.536KB constant memory，49.152KB shared memory and 32768 32-bit registers per block，14 multiprocessor，448 CUDA cores，1.15GHz。

Software

OS：**Windows 7** Enterprise Edition；

Compiler：**Microsoft** Visual Studio 2008 **C++** compiler；

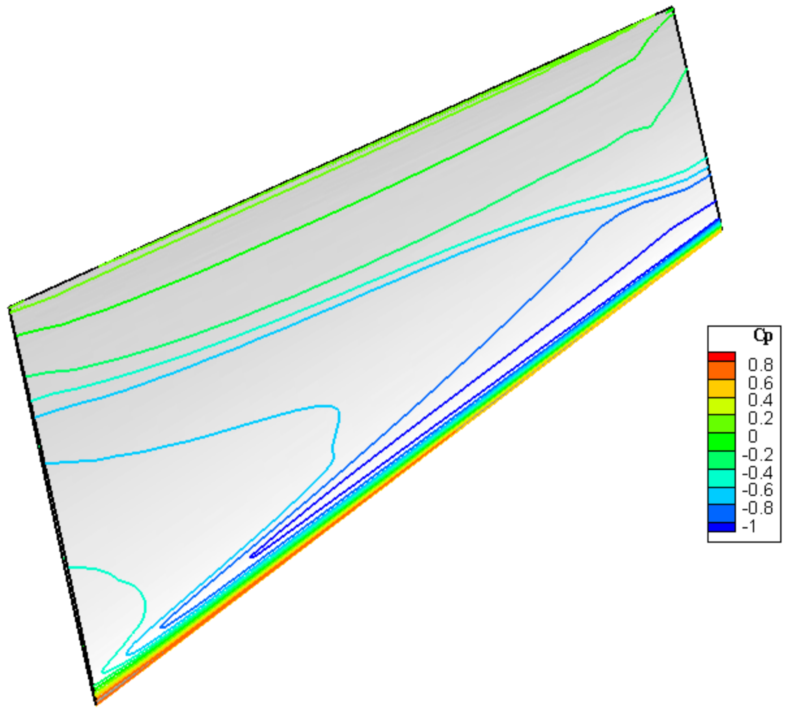
CUDA：CUDA Toolkit **3.1** and SDK；

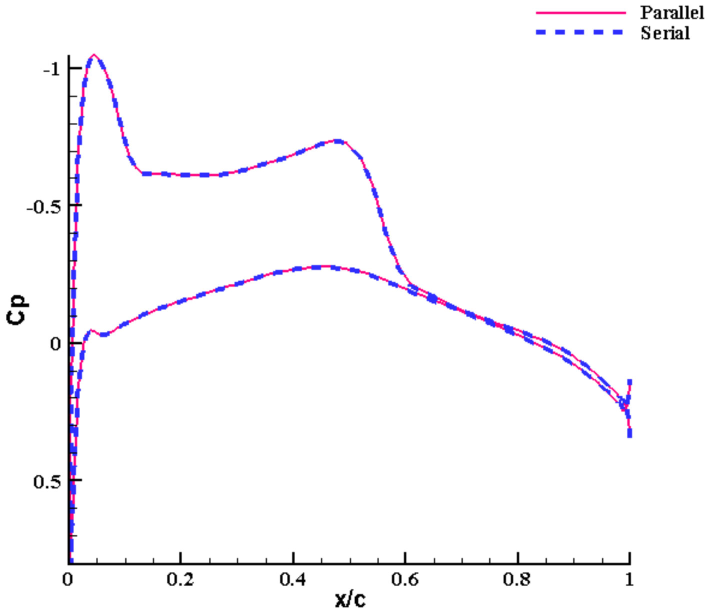


ORENA M6 Wing 244800（51x30x160）Mesh

Computation error

	CL	CD	CZ	CM
Serial	0.268945	0.022390	0.005948	-0.126988
CUDA	0.269663	0.022446	0.005969	-0.127724
Relative	0.3%	0.3%	0.4%	0.6%





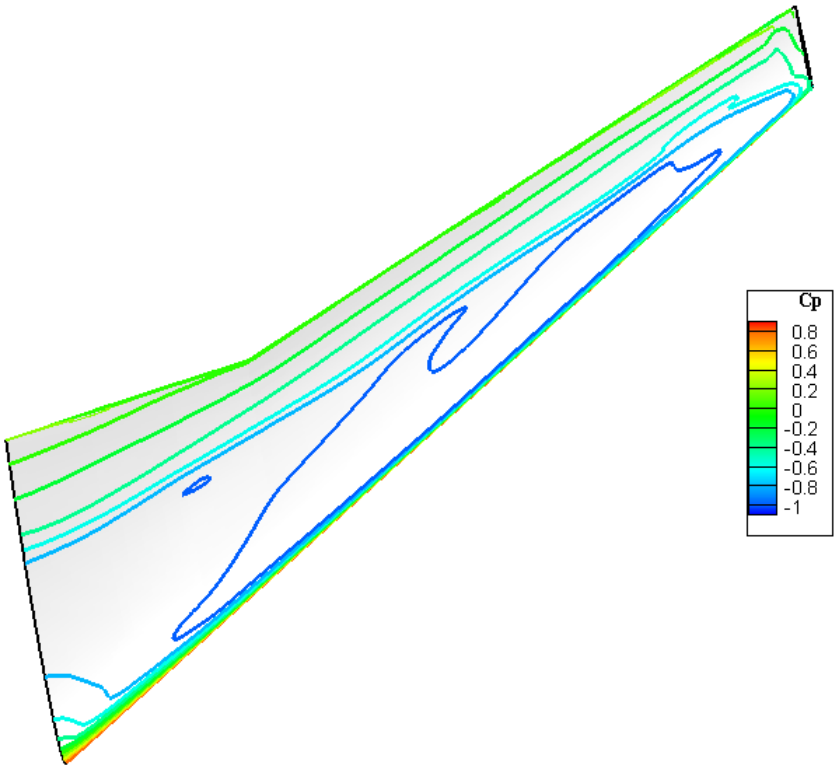
Pressure Distribution span section of 44%

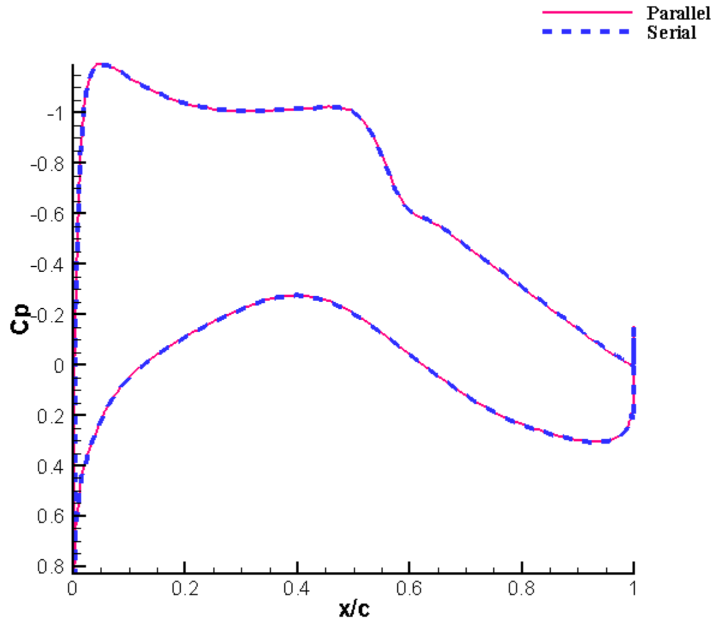
	Serial	Parallel	Speedup
OutPutFlow	15041.5s	740.0s	20.3
OutPutFlow*	14903.4s	601.9s	24.8

Another Wing 1676480（208x65x124）Mesh,Ma=0.785,AOA=2.13,Re=2.0E+07

Computation error

	CL	CD	CZ	CM
Serial	0.519426	0.022840	-0.046544	1.349560
CUDA	0.518257	0.022661	-0.046310	1.346366
Relative	0.2%	0.8%	0.5%	0.2%





Pressure Distribution span section of 55%

	Serial	Parallel	Speedup
OutPutFlow	139751.5s	4652.4s	30.0
OutPutFlow*	138926.7s	3769.8s	36.9

Conclusion and Future Work

- RANS solver on GPU get 25X speedup for M6 Wing and 37X for another Wing without sacrifice in accuracy

- Next Step will scale up on GPU cluster

Acknowledgement

This research is financially supported by Academic Partnership Program from NVIDIA

Contact Information

James Lin （林新华）lin-xh@sjtu.edu.cn

SJTU CUDA Center of Excellence

High Performance Computing Center, SJTU

Bring Many-core Thinking to
High End Research and Education