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Optimizing Memory Layout of Hyperplane Ordering for Vector Supercomputer SX-Aurora TSUBASA

Background and Motivation

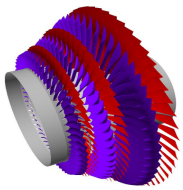
- Various phenomena in the real world can be reproduced more realistically by large-scale simulations using supercomputer systems.
- There are still many issues to be addressed in the real world, and the impact of problems with social infrastructures (ex. gas and steam turbines) on our society is immeasurable.

Necessary to conduct a numerical simulation of a turbine using a supercomputer to simulate various phenomena occurring in the turbine in order to predict such failures in advance.

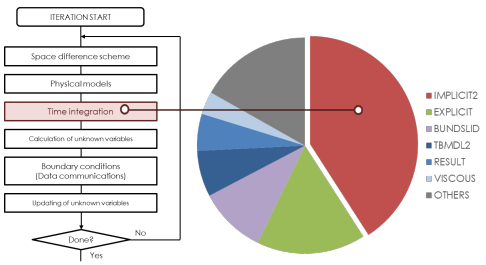
http://www.mhi-global.com

Numerical Turbine Code

Flowchart and Cost Distribution of Numerical Turbine

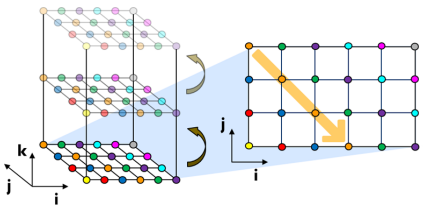


Full-annulus Simulation by Numerical Turbine

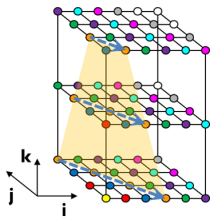


The time integration routine uses the LU-SGS scheme.
A hyperplane ordering method is adopted for vectorization.

2D Hyperplane



3D Hyperplane



	Vector Length	Memory Access
2D Hyperplane	Short	Direct Access
3D Hyperplane	Long	Indirect Access

Proposal - Optimizing Memory-access Pattern -

Specification of SX-Aurora TSUBASA

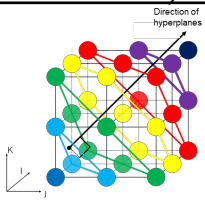
SX-Aurora TSUBASA (Vector Engine: Type 10B)	
Form Factor	
Vector Length	256 elements (16k bits)
Vector Cores	8
Frequency	1.4GHz
Flops/core	268.8GF (DP)
Flops/processor	2150.4GF (DP)
Cache Capacity	16MB (shared)
Mem. Bandwidth	1.2TB/s
Mem. Capacity	48GB

- The maximum vector length of SX-Aurora TSUBASA is 256.
- Applications should have long loop lengths to exploit the high performance.

- 3D hyperplane provides long vector lengths.
- The method is accompanied by a high memory load.

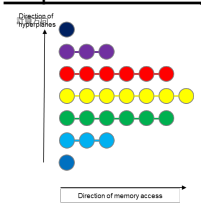
Our proposed 3D hyperplane can reduce indirect accesses by changing the data layout.

Original 3D Data Layout



Indirect memory accesses

Proposed Data Layout

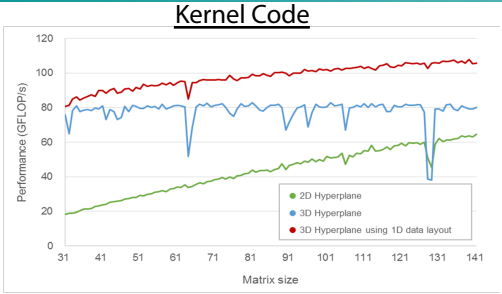


Sequential memory accesses

Indirect Mem Access op.	Original 3D Hyperplane	Proposed 3D Hyperplane
Vector Gather op.	228	162
Vector Scatter op.	20	0

Evaluation Results

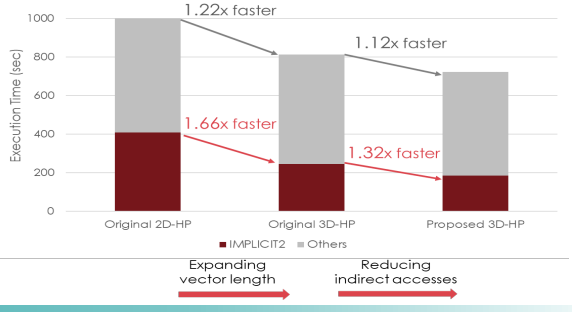
Kernel Code



The proposed method impoves the performance by up to 2.77x, and 1.27x on average, compared with the original (3D hyperplane).

Full Application (Numerical Turbine Code)

91x91x181 grid points for each stator and rotor passage



Conclusions and Future work

- The 3D hyperplane ordering method is suitable for SX-Aurora TSUBASA because the method can provide long vector lengths.
- Our proposed 3D hyperplane ordering method further improves the performance by reducing indirect memory accesses.
- Future work: examine the effect of the method on other applications and widly used SIMD architectures.

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