平成27年度地球シミュレータ利用報告会（品川） 2016年 3月 11日

災害・ものづくり系シミュレーションと
スパコンからのイノベーション

東京工業大学　学術国際情報センター

青木　尊之

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TSUBAME 2.5

System (58 racks)

1442 nodes: 2952 CPU sockets,
4264 GPUs

Performance: 224.7 TFLOPS (CPU) ※ Turbo boost
5.562 PFLOPS (GPU)
Total: **17.1** PFLOPS

Rack (30 nodes)

Performance: **122** TFLOPS
Memory: 2.28 TB

Compute Node
(3 Tesla **K20X** GPUs)

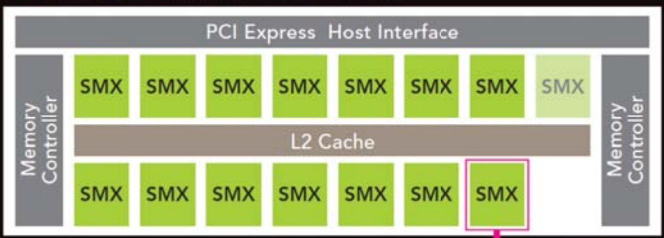
Performance: 4.08 TFLOPS
Memory: 58.0GB(CPU)
+18GB(GPU)

GPU: Kepler core NVIDIA Tesla K20X

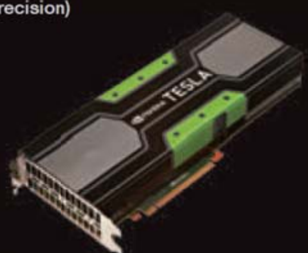
GP GPU

Details of GPU

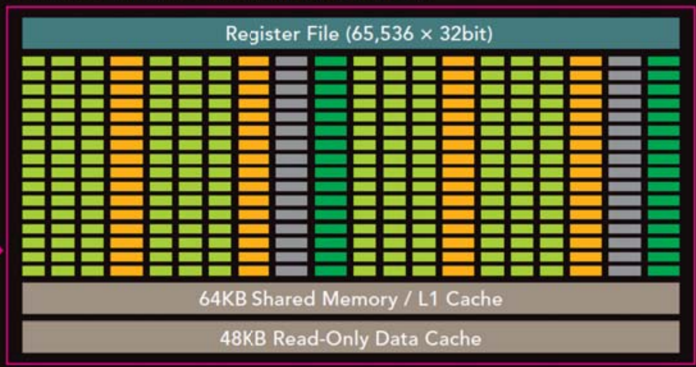
K20X Architecture (Kepler GK110 Core)



Peak performance : 1.31 TFLOPS (double precision)
3.95 TFLOPS (single precision)
Shader clock : 732 MHz
Number of CUDA cores (SP) : 2,688 cores
Streaming Multiprocessor (SMX) : 14 SMX
Writable L2 cache: 1.5MB
Memory bandwidth : 250GB / sec
Memory clock : 2.6GHz (GDDR5)
ECC support:
internal and external memory
On-board memory: 6GB



Details of SM (Streaming Multiprocessor)



CUDA core (SP) / SMX : 192 cores
DP unit / SMX : 64 SFU / SM : 32 units
Warp scheduler / SMX : 4 units
Shared memory / SMX : 16KB or 32KB or 48KB
Writable L1 cache / SMX : 48KB or 32KB or 16KB
Read-only data cache / SMX: 48KB

Core
DP Unit
LDST
SFU

TOP 500 Ranking 2014 Jun

GP GPU

Rank	Site	System	Cores	Rmax (TFlop/s)	Rpeak (TFlop/s)	Power (kW)	
1	National Super Computer Center in Guangzhou China	Tianhe-2 (MilkyWay-2) - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P NUDT	3120000	33862.7	54902.4	17808	MIC Xeon Phi
2	DOE/SC/Oak Ridge National Laboratory United States	Titan - Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x Cray Inc.	560640	17590.0	27112.5	8209	GPU K20X
3	DOE/NNSA/LLNL United States	Sequoia - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM	1572864	17173.2	20132.7	7890	
4	RIKEN Advanced Institute for Computational Science (AICS) Japan	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect Fujitsu	705024	10510.0	11280.4	12660	
5	DOE/SC/Argonne National Laboratory United States	Mira - BlueGene/Q, Power BQC 16C 1.60GHz, Custom IBM	786432	8586.6	10066.3	3945	
6	Swiss National Supercomputing Centre (CSCS) Switzerland	Piz Daint - Cray XC30, Xeon E5-2670 8C 2.600GHz, Aries interconnect , NVIDIA K20x Cray Inc.	115984	6271.0	7788.9	2325	GPU K20X
7	Texas Advanced Computing Center/Univ. of Texas United States	Stampede - PowerEdge C8220, Xeon E5-2680 8C 2.700GHz, Infiniband FDR, Intel Xeon Phi SE10P Dell	462462	5168.1	8520.1	4510	MIC Xeon Phi
8	Forschungszentrum Juelich (FZJ) Germany	JUQUEEN - BlueGene/Q, Power BQC 16C 1.600GHz, Custom Interconnect IBM	458752	5008.9	5872.0	2301	
9	DOE/NNSA/LLNL United States	Vulcan - BlueGene/Q, Power BQC 16C 1.600GHz, Custom Interconnect IBM	393216	4293.3	5033.2	1972	
10	Government United States	Cray XC30, Intel Xeon E5-2697v2 12C 2.7GHz, Aries interconnect Cray Inc.	225984	3143.5	4881.3		
11	Exploration & Production - Eni S.p.A. Italy	HPC2 - iDataPlex DX360M4, Intel Xeon E5-2680v2 10C 2.8GHz, Infiniband FDR, NVIDIA K20x IBM	62640	3003.0	4006.3	1067	GPU K20X
12	Leibniz Rechenzentrum Germany	SuperMUC - iDataPlex DX360M4, Xeon E5-2680 8C 2.70GHz, Infiniband FDR IBM	147456	2897.0	3185.1	3423	
13	GSIC Center, Tokyo Institute of Technology Japan	TSUBAME 2.5 - Cluster Platform SL390s G7, Xeon X5670 6C 2.93GHz, Infiniband QDR, NVIDIA K20x NEC/HP	76032	2785.0	5735.7	1399	GPU K20X
14	National Supercomputing Center in Tianjin China	Tianhe-1A - NUDT YH MPP, Xeon X5670 6C 2.93 GHz, NVIDIA 2050 NUDT	186368	2566.0	4701.0	4040	GPU M2050

TOP500 SUPERCOMPUTER SITES

Inexpensive

High Performance

Low Electronic Consumption

TOP 500 Ranking 2015 November

RANK	SITE	SYSTEM	CORES	RMAX (TFLOP/S)	RPEAK (TFLOP/S)	POWER (KW)
1	National Super Computer Center in Guangzhou China	**Tianhe-2 (MilkyWay-2)** - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P NUDT	3,120,000	33,862.7	54,902.4	17,808
2	DOE/SC/Oak Ridge National Laboratory United States	**Titan** - Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x Cray Inc.	560,640	17,590.0	27,112.5	8,209
3	DOE/NNSA/LLNL United States	**Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM	1,572,864	17,173.2	20,132.7	7,890
4	RIKEN Advanced Institute for Computational Science (AICS) Japan	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect Fujitsu	705,024	10,510.0	11,280.4	12,660
5	DOE/SC/Argonne National Laboratory United States	**Mira** - BlueGene/Q, Power BQC 16C 1.60GHz, Custom IBM	786,432	8,586.6	10,066.3	3,945
6	DOE/NNSA/LANL/SNL United States	**Trinity** - Cray XC40, Xeon E5-2698v3 16C 2.3GHz, Aries interconnect Cray Inc.	301,056	8,100.9	11,078.9	
7	Swiss National Supercomputing Centre (CSCS) Switzerland	**Piz Daint** - Cray XC30, Xeon E5-2670 8C 2.600GHz, Aries interconnect , NVIDIA K20x Cray Inc.	115,984	6,271.0	7,788.9	2,325
8	HLRS - Höchstleistungsrechenzentrum Stuttgart Germany	**Hazel Hen** - Cray XC40, Xeon E5-2680v3 12C 2.5GHz, Aries interconnect Cray Inc.	185,088	5,640.2	7,403.5	
9	King Abdullah University of Science and Technology Saudi Arabia	**Shaheen II** - Cray XC40, Xeon E5-2698v3 16C 2.3GHz, Aries interconnect Cray Inc.	196,608	5,537.0	7,235.2	2,834
10	Texas Advanced Computing Center/Univ. of Texas United States	**Stampede** - PowerEdge C8220, Xeon E5-2680 8C 2.700GHz, Infiniband FDR, Intel Xeon Phi SE10P Dell	462,462	5,168.1	8,520.1	4,510

MIC Xeon Phi

GPU K20X

GPU K20X

MIC Xeon Phi

Top500 のうち

69 システムが GPU
27 システムが MIC

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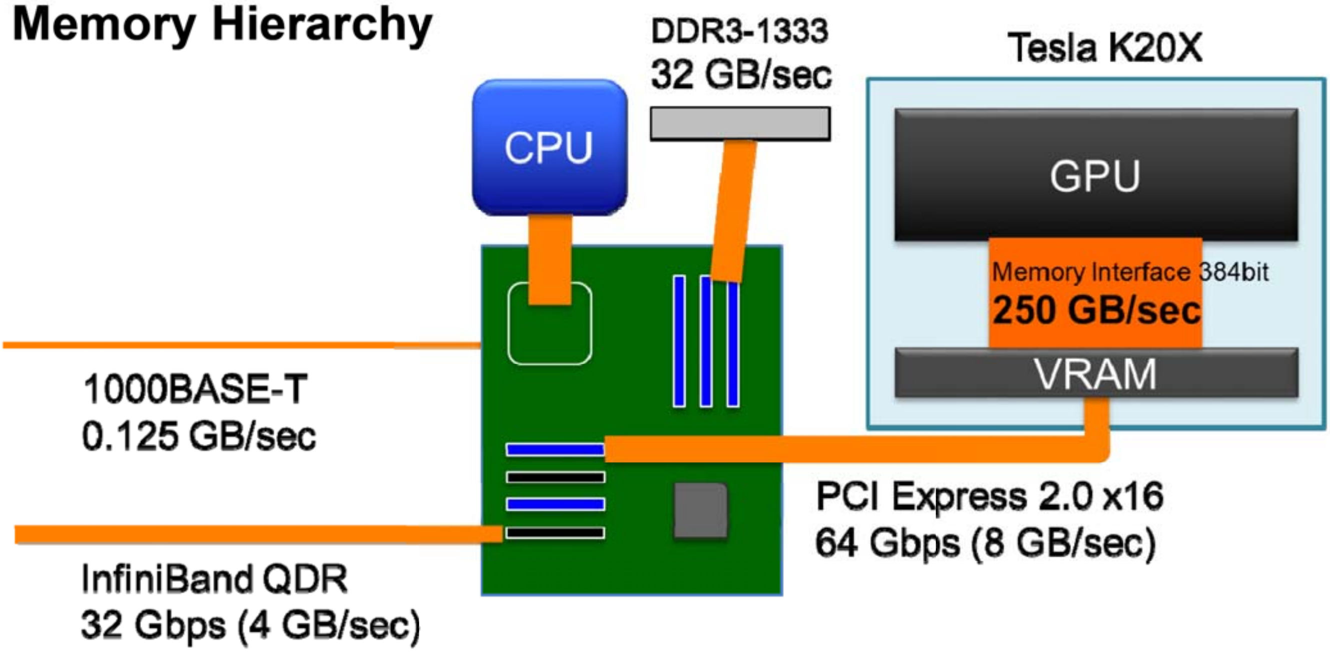
Bandwidth Bottlenecks

■ Memory Hierarchy



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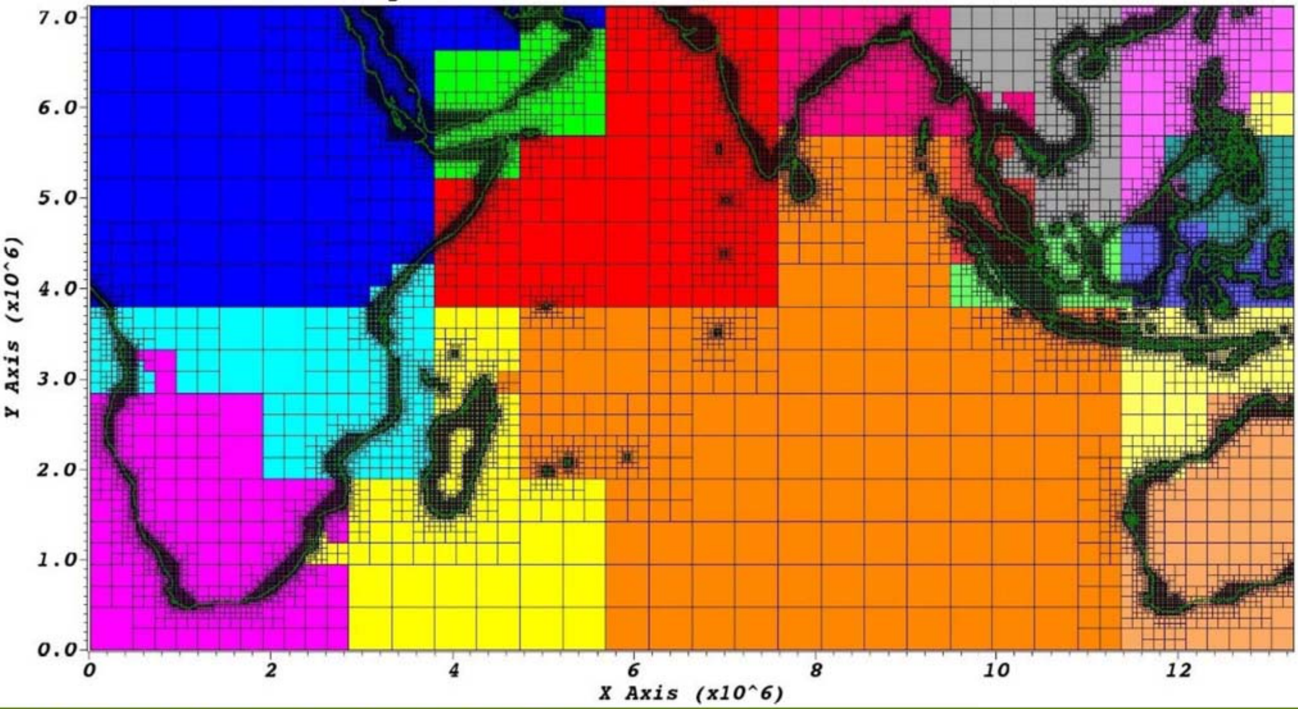
RIMES Regional Integrated Multi-Hazard Early Warning System for Africa and Asia



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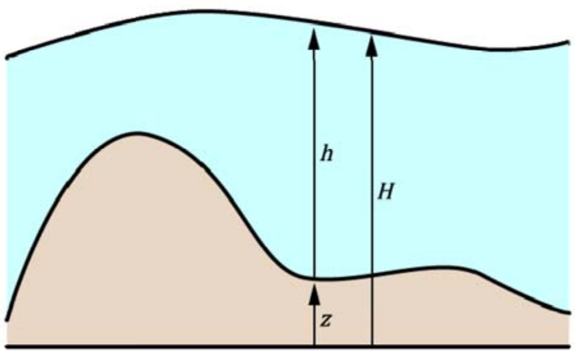
Shallow Water Solver

$$\frac{\partial \boldsymbol{U}}{\partial t}+\frac{\partial \boldsymbol{F}}{\partial x}+\frac{\partial \boldsymbol{G}}{\partial y}=\boldsymbol{S} \qquad \boldsymbol{U}=\begin{bmatrix} h \\ hu \\ hv \end{bmatrix},\ \boldsymbol{F}=\begin{bmatrix} hu \\ hu^2+\frac{1}{2}gh^2 \\ huv \end{bmatrix},\ \boldsymbol{G}=\begin{bmatrix} hv \\ huv \\ hv^2+\frac{1}{2}gh^2 \end{bmatrix}$$

Two GPU kernels:

- Characteristics Method for Deep Ocean
  Directional splitting (fractional step)
- FVM for the area including Coastlines
  A lot of exceptional processes



Characteristics Method

GP GPU

Factorization:

$$\frac{\partial U}{\partial t}+A\frac{\partial U}{\partial x}=0 \qquad A=\frac{\partial F}{\partial U}=\begin{bmatrix}0 & 1\\ \Gamma^2-u^2 & 2u\end{bmatrix}$$

for $\Gamma=\sqrt{gh}$

$$\Gamma^{n+1}=\frac{1}{2}\left\{\Gamma^{+\,n+1}+\Gamma^{-\,n+1}+\frac{1}{2}\left(u^{+}-u^{-}\right)\right\}$$

$$u^{n+1}=\frac{1}{2}\left\{u^{+}-u^{-}+2\left(\Gamma^{+}-\Gamma^{-}\right)\right\}$$

Riemann invariants :

$$\frac{\partial W}{\partial t}+\Lambda\frac{\partial W}{\partial x}=0 \qquad W=\begin{bmatrix}\Gamma+\frac{1}{2}u\\ \Gamma-\frac{1}{2}u\end{bmatrix},\quad \Lambda=\begin{bmatrix}u+\Gamma & 0\\ 0 & u-\Gamma\end{bmatrix}$$

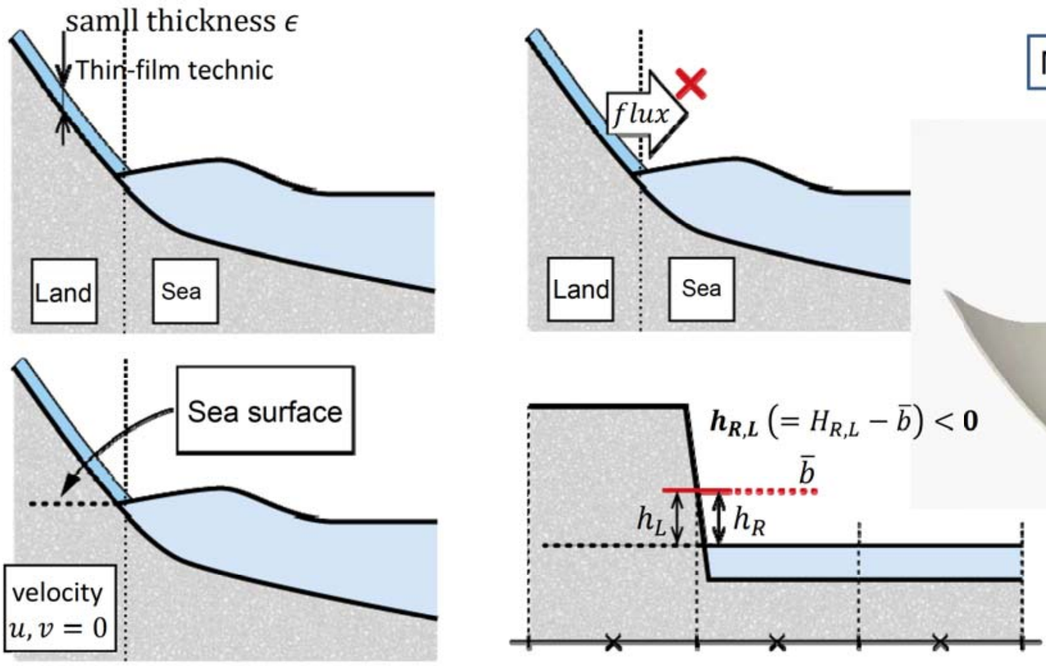
$$\frac{\partial \Gamma^{\pm}}{\partial t}+\lambda^{\pm}\frac{\partial \Gamma^{\pm}}{\partial x}=0 \qquad \Gamma^{\pm}=\Gamma\pm\frac{1}{2}u$$

Semi-Lagrangian Scheme

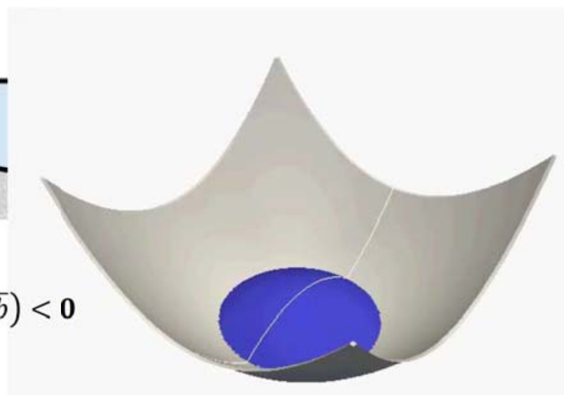
$$h^{n+1},\quad (hu)^{n+1}$$

Inundation at coastlines

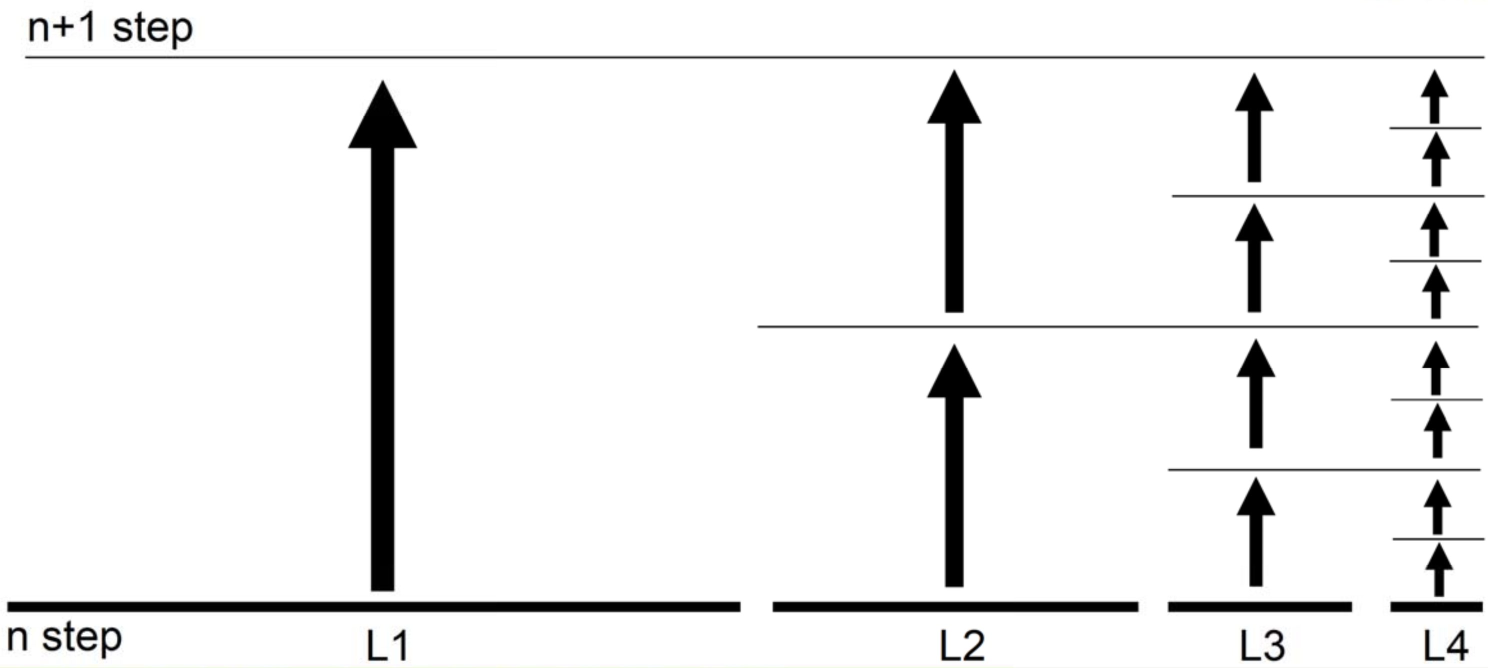
GP GPU



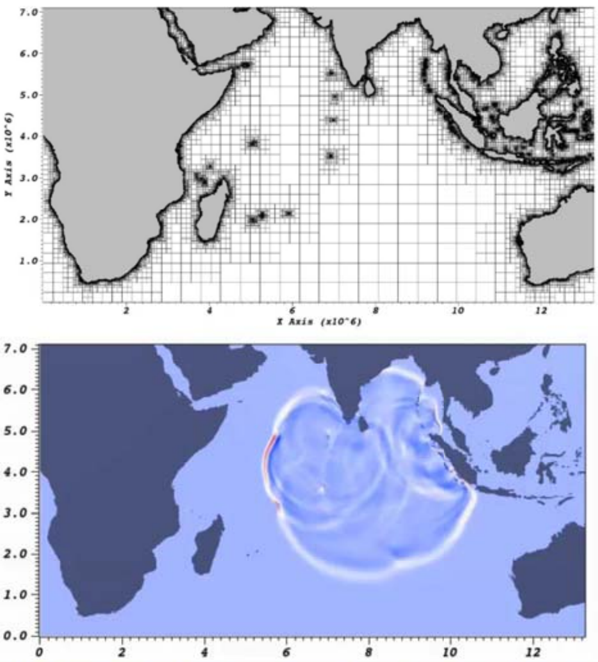
Many exceptional treatments

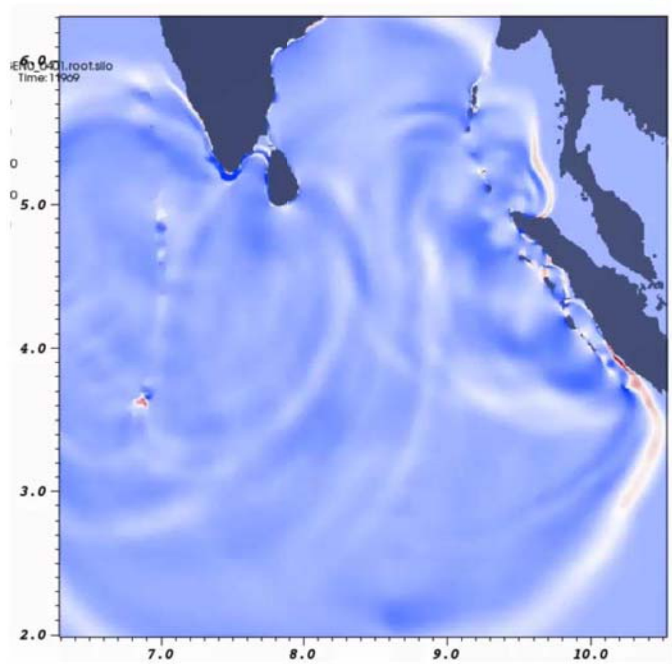


Time-step Control (Sub-cycling)



Global Tsunami Simulation





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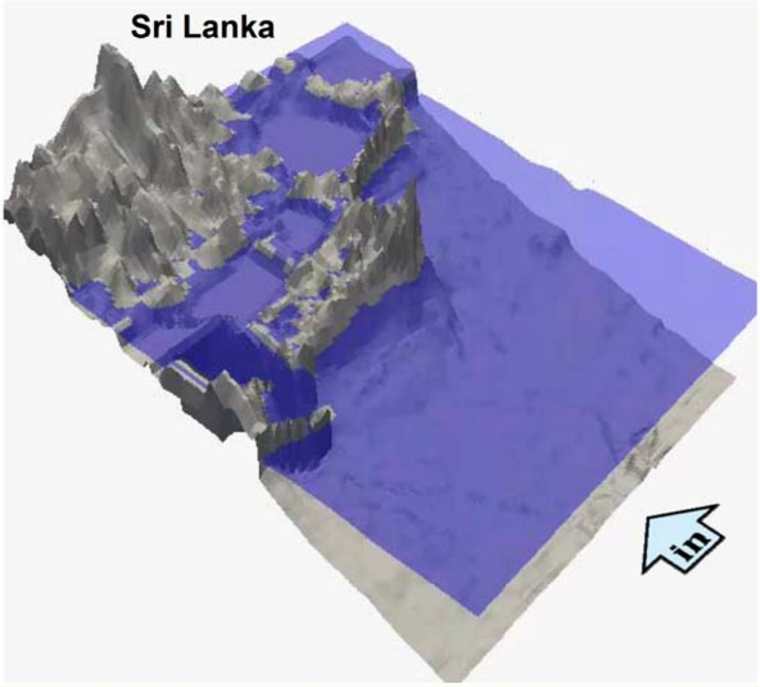
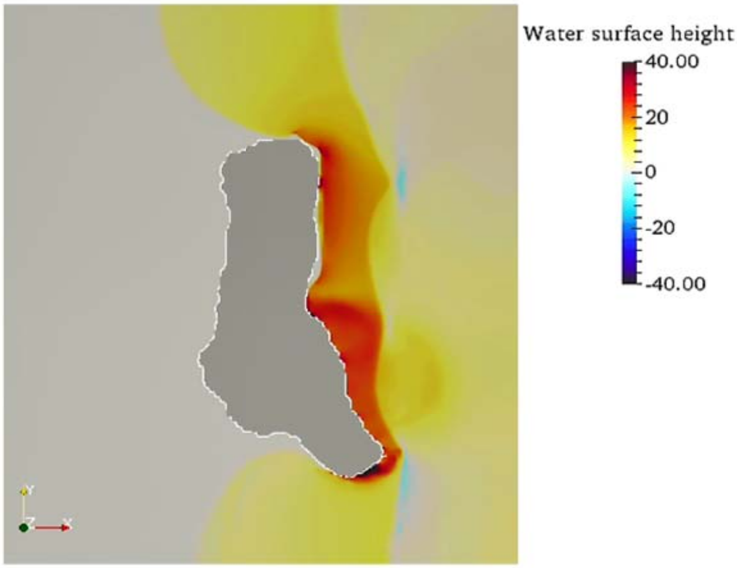
Inundation Validation



Comoro Island



津波の建物への影響

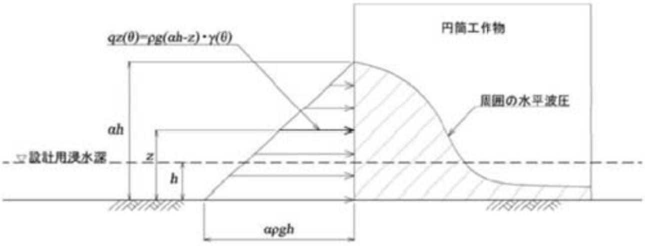
A Tsunami Shelter Project

Urgent Electric Power Supply

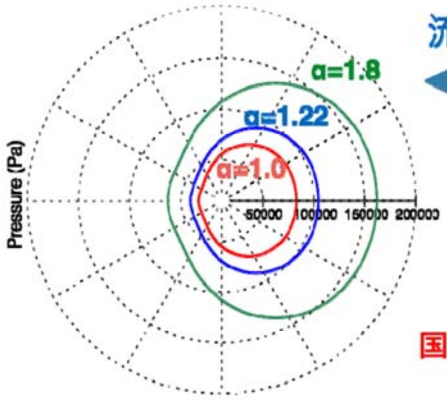
Vertical Axis Wind Turbine

～ 100kW

円筒形状の構造物への津波の作用



流れの方向



U=10m/s
g=9.8m/s^2
h=10m
Fr=1.01
—> α=1.22

$$qz(\theta) = \rho g(\alpha h - z)\cdot\gamma(\theta)$$

$qz(\theta)$ ：構造設計用の円周方向の津波波圧

θ ：津波の来襲方向を0°とした円筒工作物の角度

α ：水深係数

＊1.0~3.0が使用されている

$$\alpha = \begin{cases} 1.0 & (F_r < 0.9) \\ 2.0F_r - 0.8 & (0.9 \le F_r \le 1.3) \\ 1.8 & (1.3 \le F_r) \end{cases}$$

F_r ：フルード数　$F_r = U/\sqrt{gh}$　U ：津波の流速 (m/s)

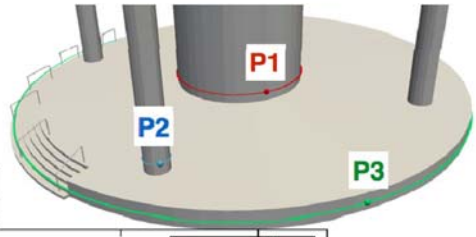
$\gamma(\theta)$ ：円周方向の低減係数

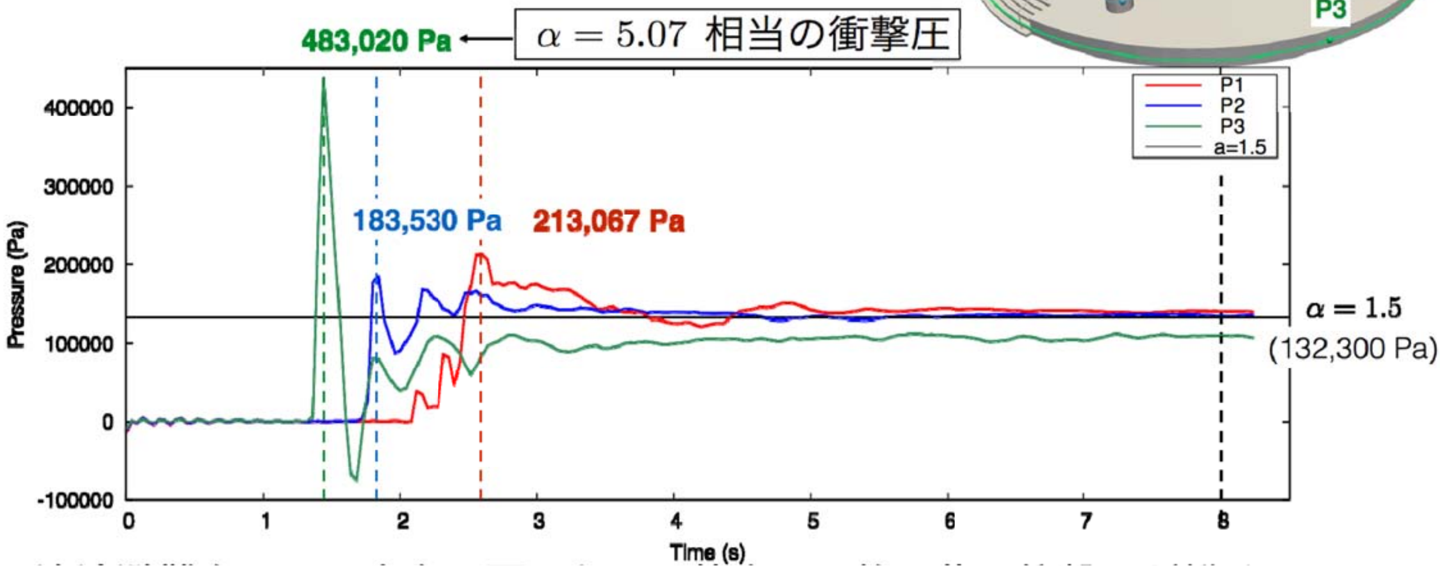
$$\gamma(\theta) = \sum_{m=0}^{3} p_m \cos(m\theta)$$

$$p_0 = 0.680,\ p_1 = 0.340,\ p_2 = 0.015,\ p_3 = -0.035$$

国土交通省港湾局：「港湾の津波避難施設の設計ガイドライン（平成25年10月）」

柱にかかる圧力の時間履歴



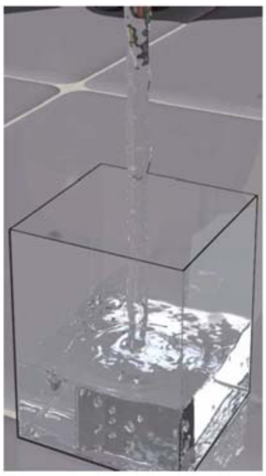


※ 津波避難タワーの土台正面に静水圧の5倍の衝撃圧がかかる

気液二相流（有限体積法）

GP GPU

Two-Phase Flows



Mesh Method (Surface Capture) to solve Navier Stokes equation

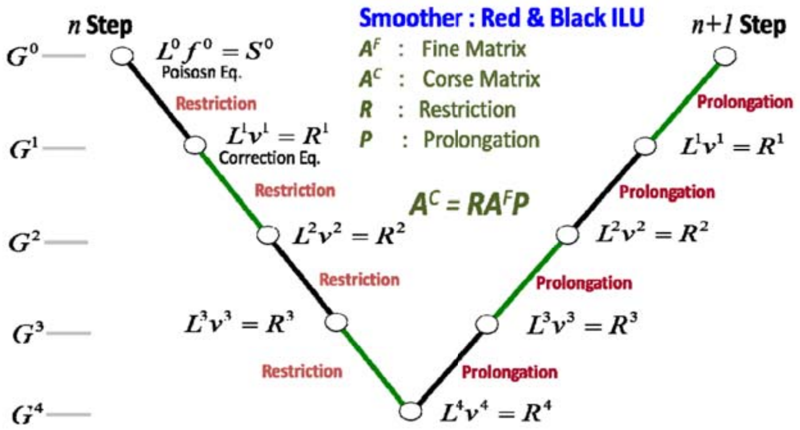
- Navier-Stokes solver : Fractional Step
- Time integration : 3rd TVD Runge-Kutta
- Advection term : 5th WENO
- Diffusion term : 4th FD
- Poisson : MG-BiCGstab
- Surface tension : CSF model
- Surface capture : CLSVOF(THINC + Level-Set)

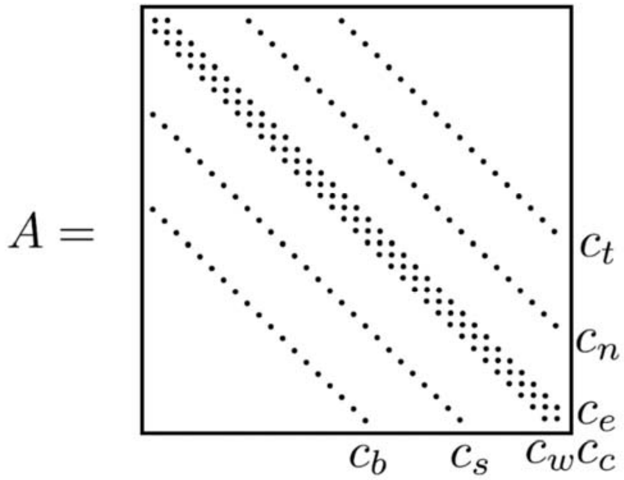
Fine meshes should be assigned around gas-liquid interfaces

Sparse Matrix Solver

$$\mathbf{A}\boldsymbol{x} = \boldsymbol{b} \quad \textit{for} \quad \nabla \cdot \left(\frac{1}{\rho} \nabla p \right) = \frac{\nabla \cdot \boldsymbol{u}}{\Delta t}$$

BiCGStab + MG preconditioner





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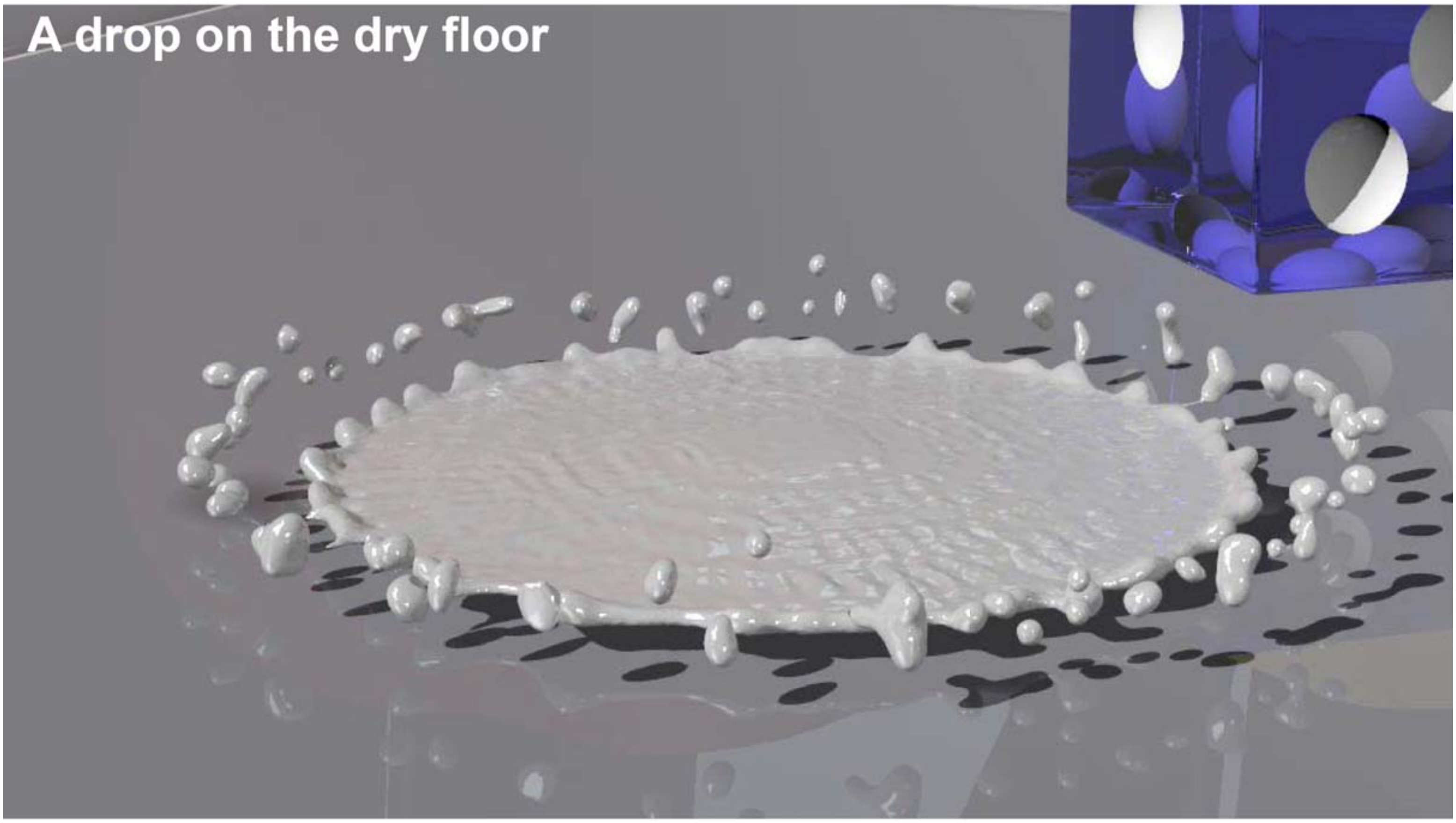
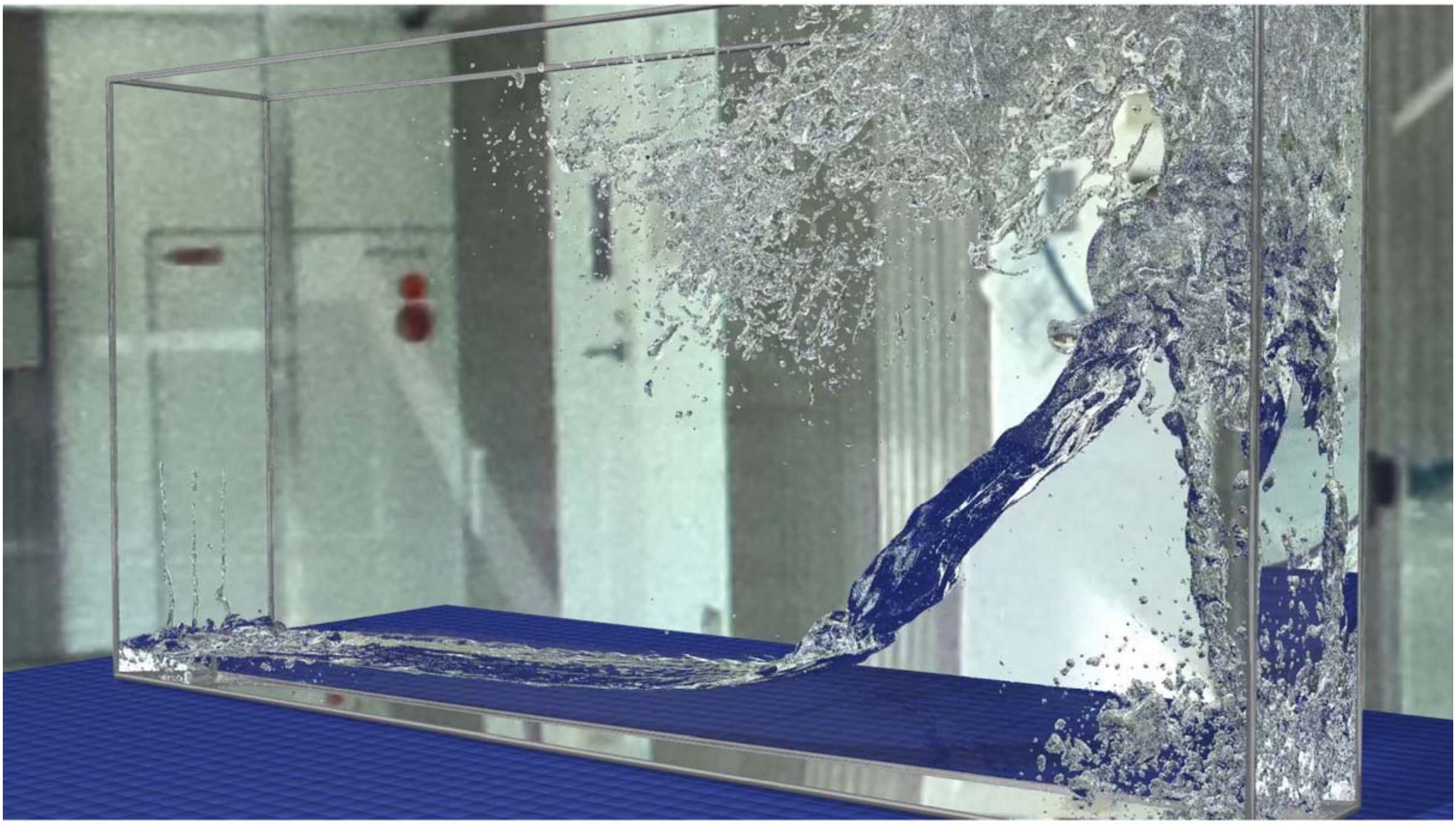
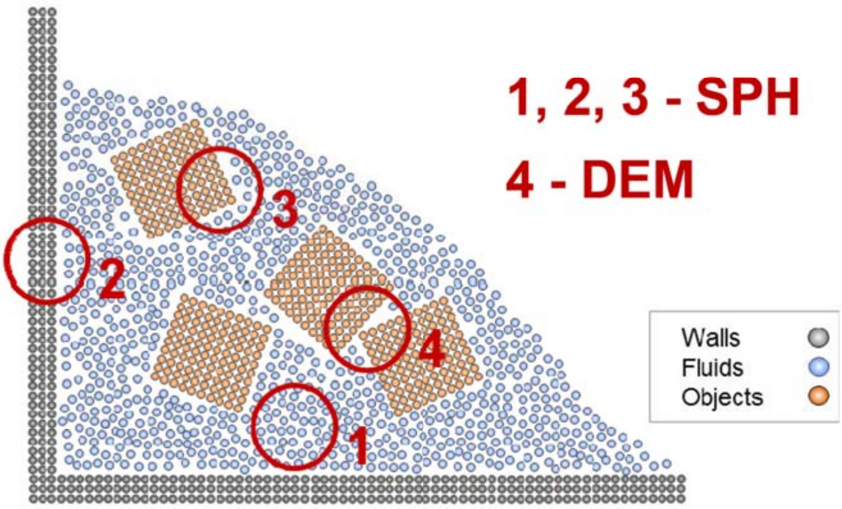




多数の瓦礫を含んだ津波シミュレーション

GP GPU

粒子法によるシミュレーション



SPH（Smoothed Particle Hydrodynamics）

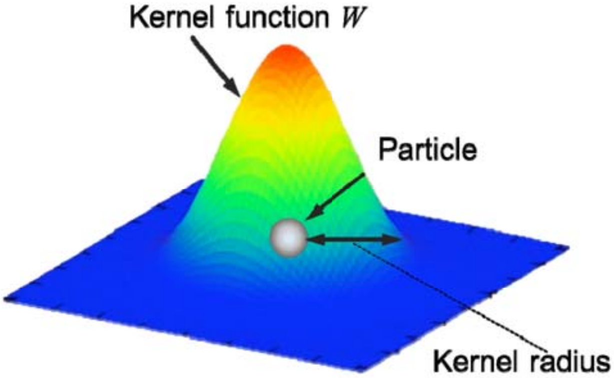
GP GPU

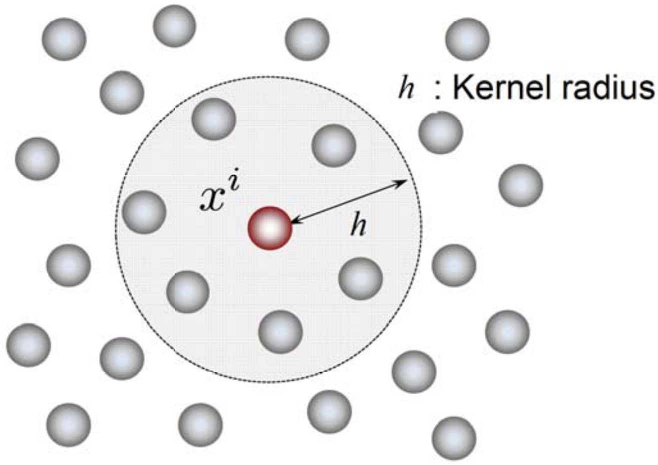
Improve SPH: Generalization of Finite Difference Operators (Imoto, Tagami 2014)

Physical property

$$\phi(\boldsymbol{x}) = \sum_j m_j \frac{\phi_j}{\rho_j} W(\boldsymbol{x} - \boldsymbol{x}_j)$$

m_j : mass ρ_j : density



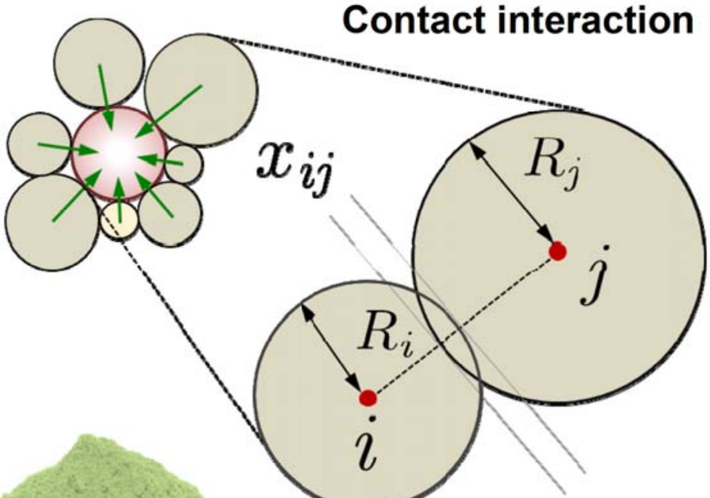


about **100** particles within the kernel

DEM (Discrete Element Method)

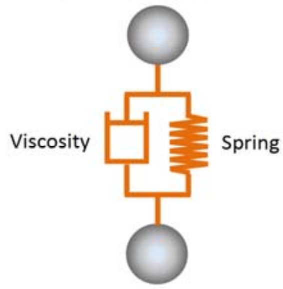
GP GPU

Contact interaction

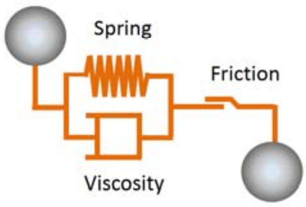


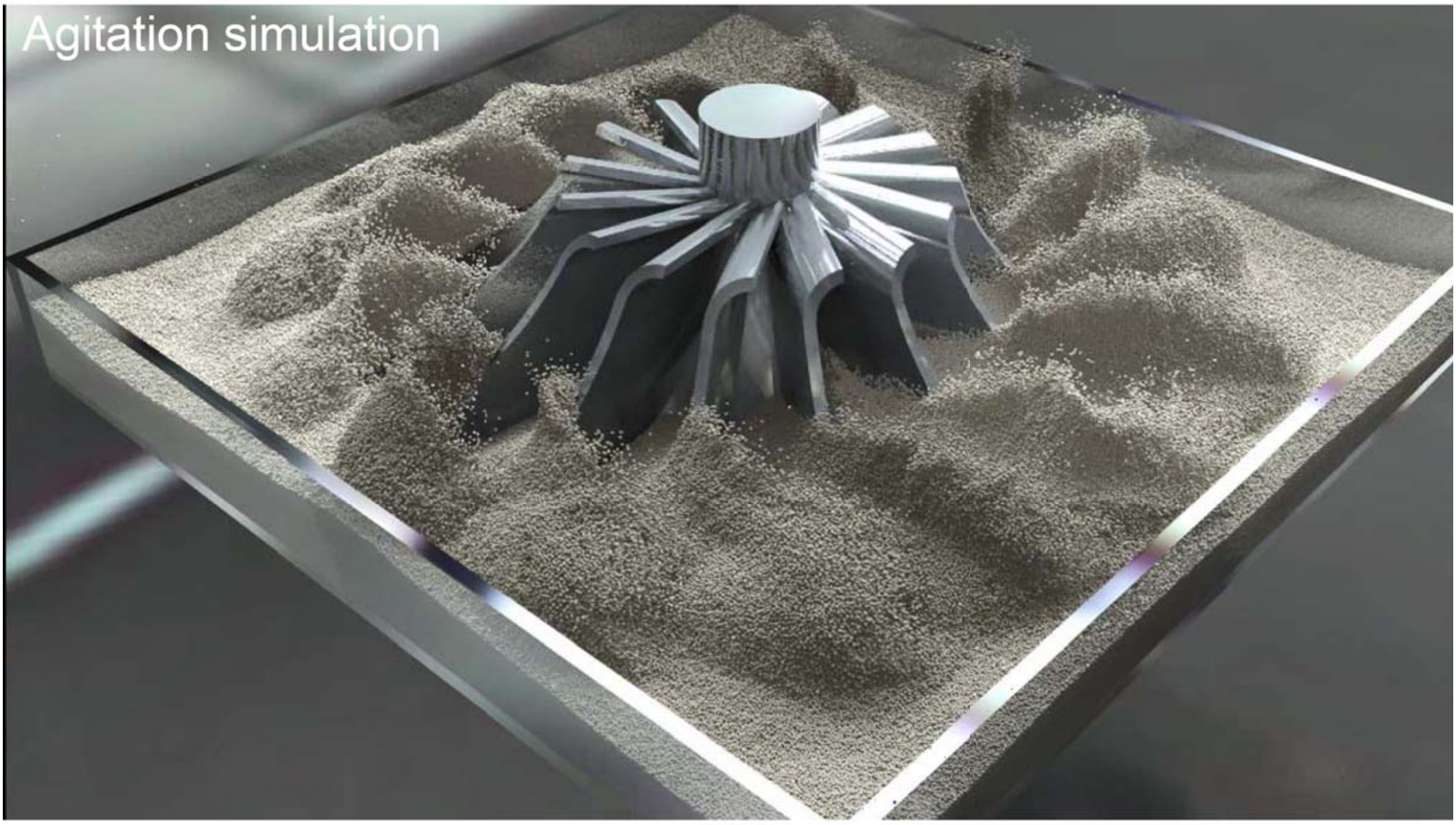
$$F_{ij} = -kx_{ij} - \gamma\dot{x}_{ij}$$

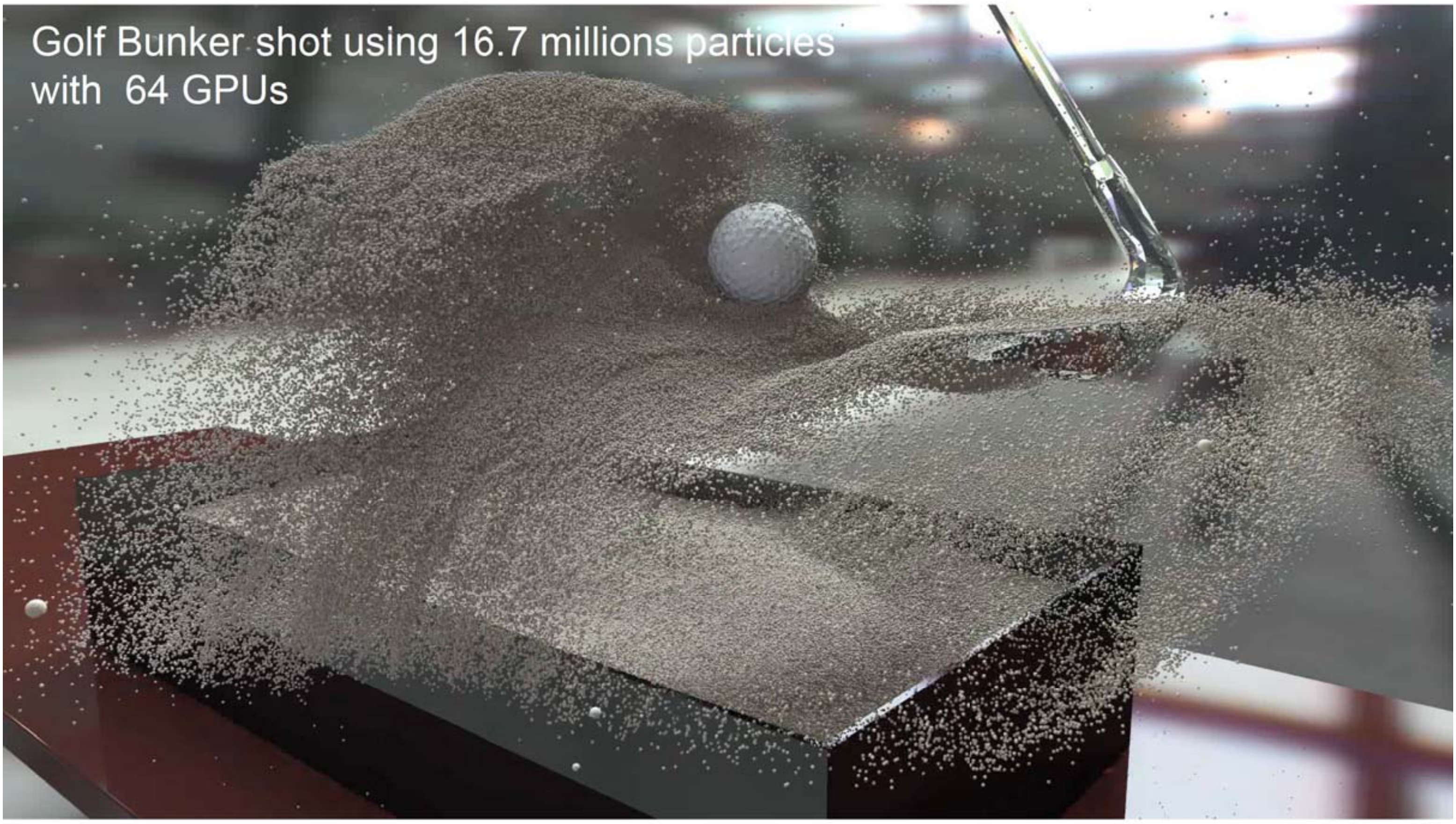
Normal direction



Tangential direction




Agitation simulation


Golf Bunker shot using 16.7 millions particles
with 64 GPUs

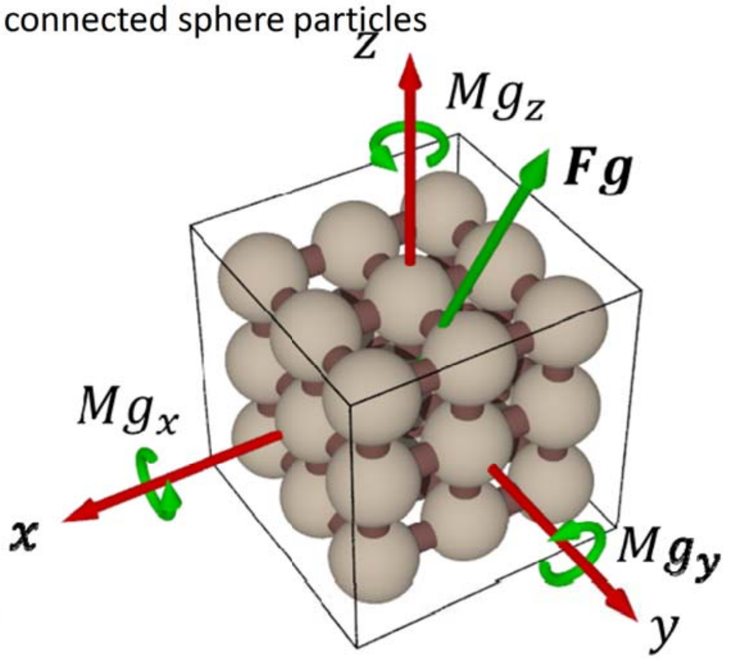
Complex Shape Objects

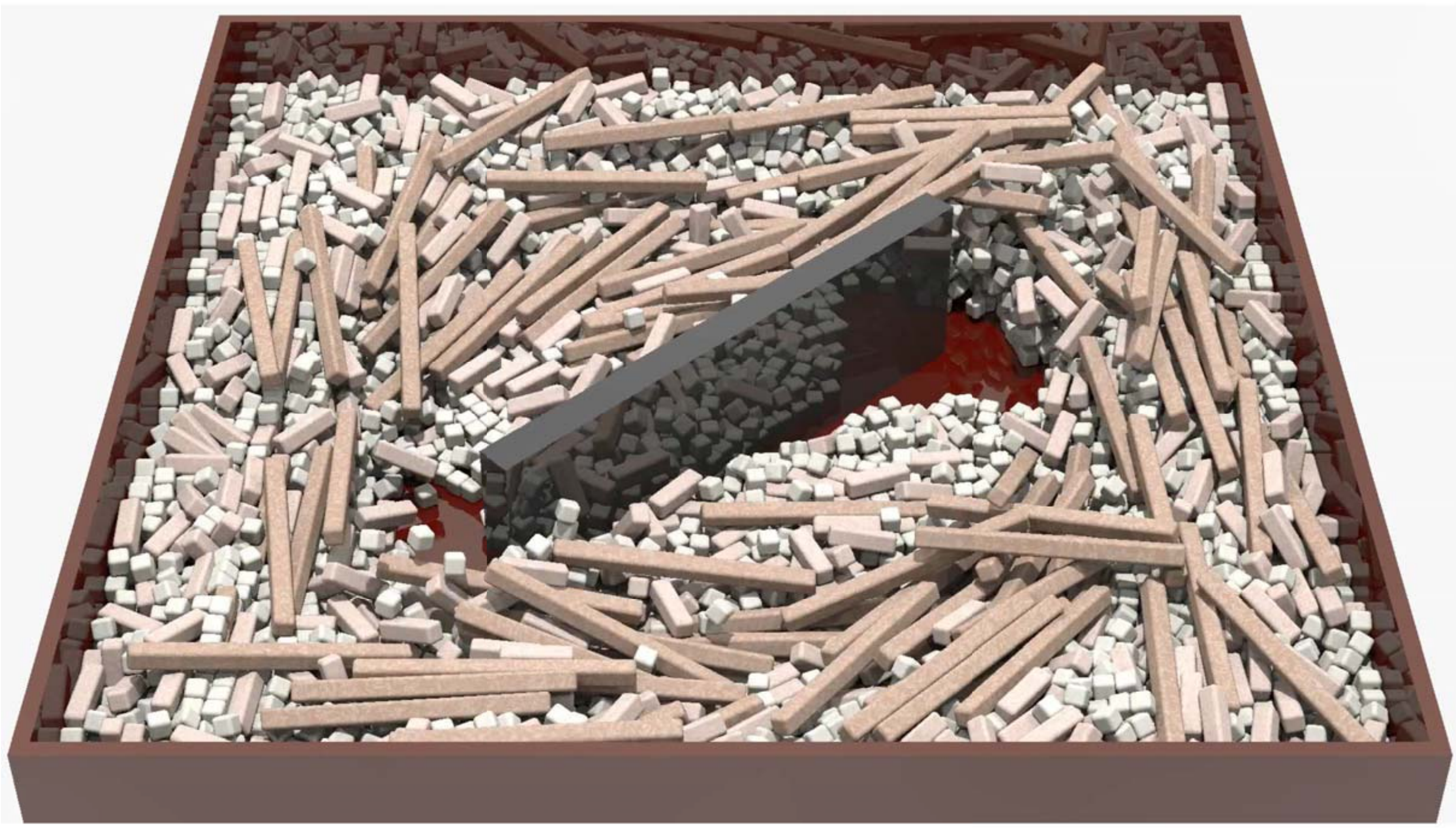
Non-spherical model described by rigidly connected sphere particles

$$Fg = \sum F \qquad Mg = \sum (x - xg) \times F$$

$$vg_{t+\Delta t/2} = vg_{t-\Delta t/2} + (Fg/mg)\Delta t$$
$$xg_{t+\Delta t} = xg_t + vg_{t+\Delta t/2}\Delta t$$
$$\omega g_{t+\Delta t/2} = \omega g_{t-\Delta t/2} + (Ig^{-1}Mg)\,\Delta t$$
$$Qg_{t+\Delta t} = \Delta Qg_{t+\Delta t/2}Qg_t$$
$$Ig_{t+\Delta t} = {R_{t+\Delta t}}^{-1}Ig_{init}R_{t+\Delta t}$$

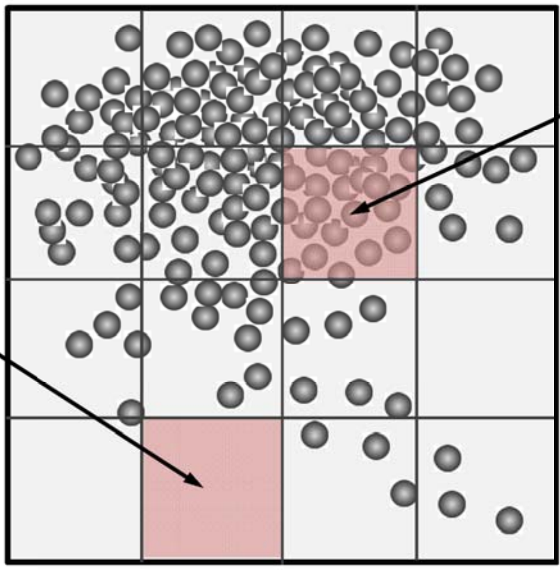
$$x_{t+\Delta t} = xg_{t+\Delta t} + Qg_{t+\Delta t}r_{init}(Qg_{t+\Delta t})^T$$
$$v_{t+\Delta t/2} = vg_{t+\Delta t/2} + \omega g_{t+\Delta t/2} \times (x_{t+\Delta t} - xg_{t+\Delta t})$$





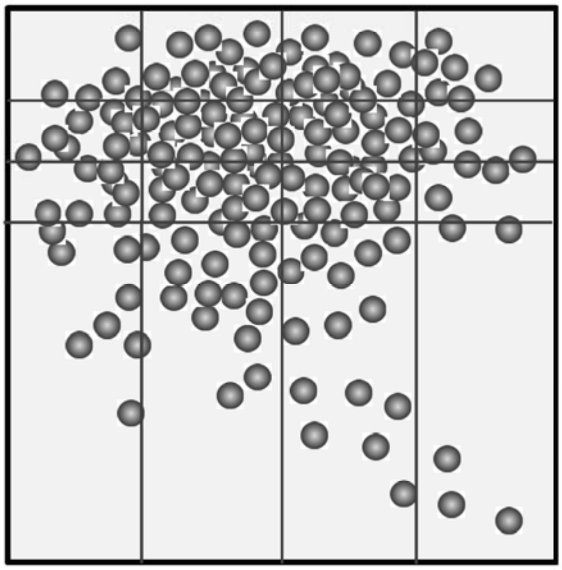
Particle Distribution

- The load imbalance problem among subdomains



Dynamic Domain Decomposition

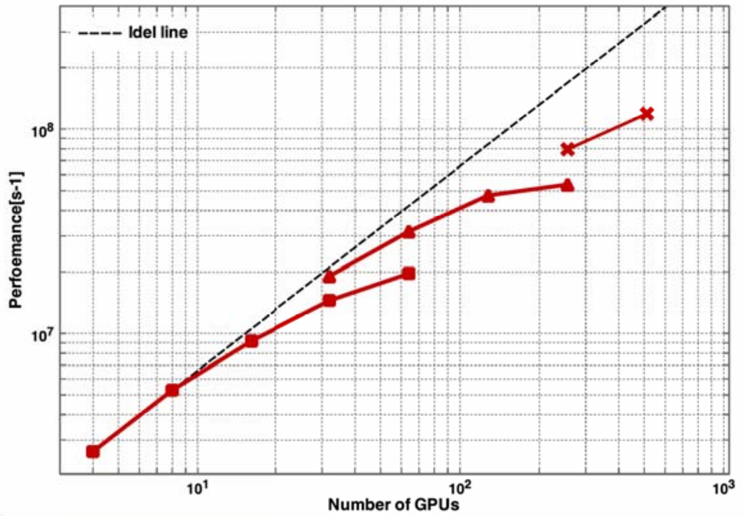
- 2-dimensional slice-grid method



Multiple GPU Scalability

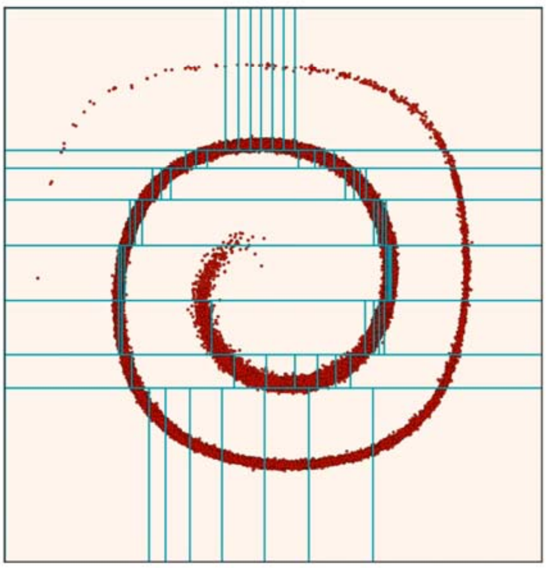
- **Conditions**

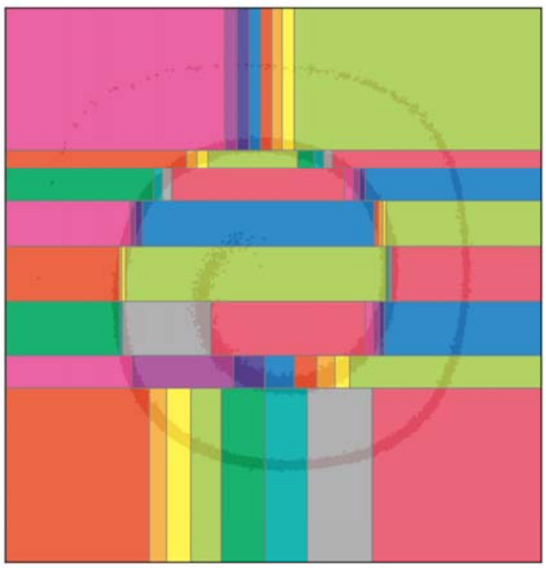
Particles : 2×10^6, 1.6×10^7, 1.29×10^8
Domain Decomposition : Dynamic load Balance using Slice Grid Method
Time-Integration : 2-stage Runge-Kutta



Sub-domains with High Aspect ratio

Slice Grid Method



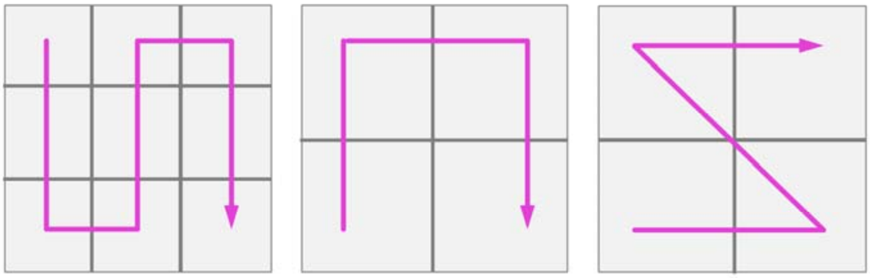


- The passive particles under vortex velocity field using 64 GPUs

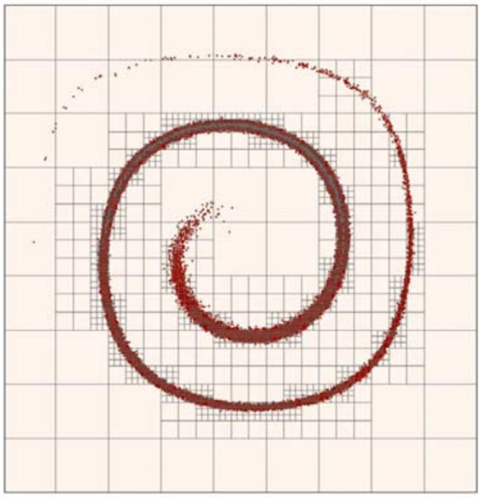
Space Filling Curves

- ✓ Construction of a tree so that each leafs contain minimum number of particles
- ✓ Each leafs is numbered by following the rules of space filling curves.

Peano | Hilbert | Morton



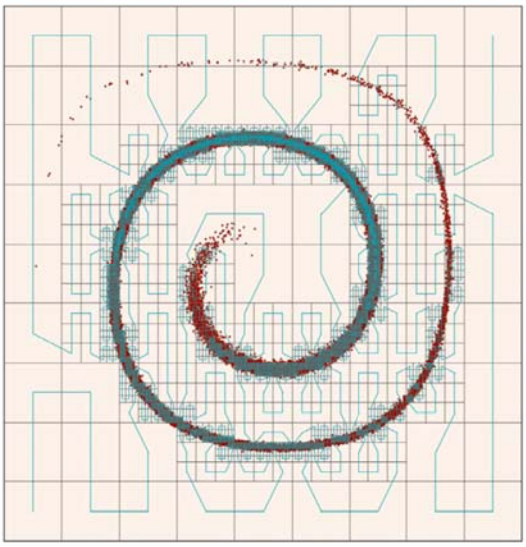
9 Cells | 4 Cells | 4 Cells



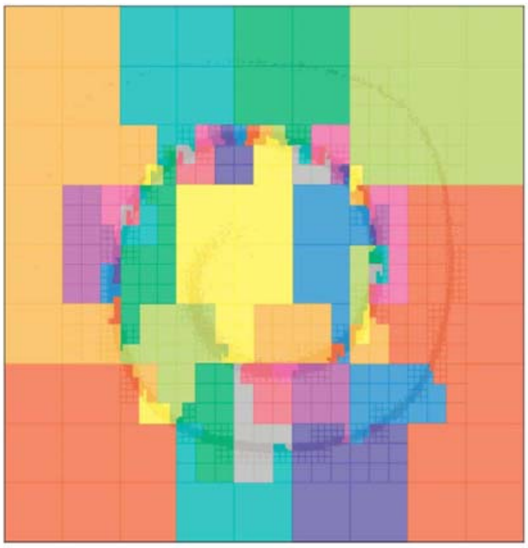
A tree-base cell refinement

Space Filling Curves

- The connections of leafs by Peano curve

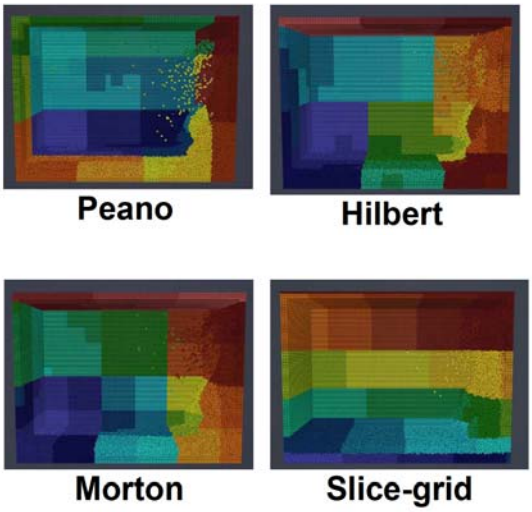


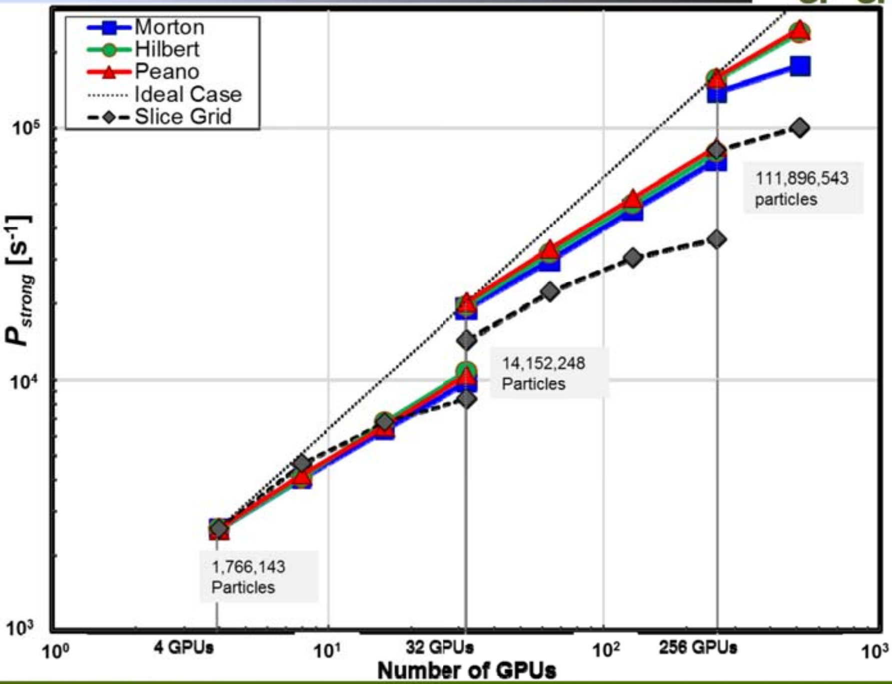
- The domain decomposition by Peano curve



Scalability on TSUBAME2.5

Comparison of 3 different SFC with slice-grid method





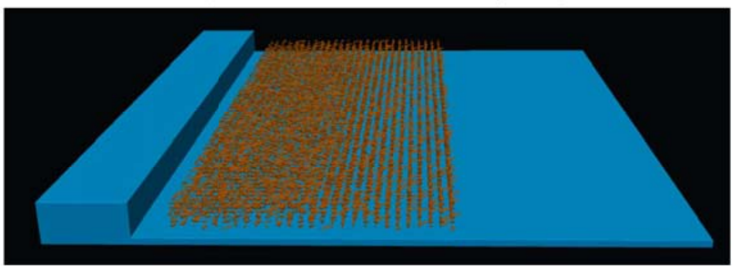
Tsunami Debris Flow

■ Including a lot of floating objects

Computational conditions

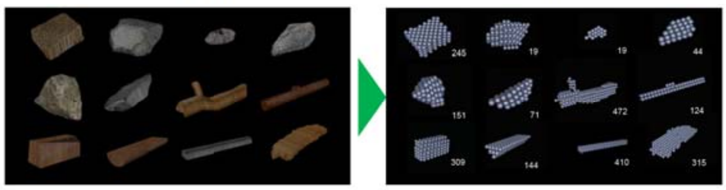
- Simulation area : 180 m × 160 m × 20 m
- Total particles : **117,561,285**
- Particles / object : 19 ~ 472
- Objects : **10368**
- Physical time (s) : 10.0
- Steps : 20,000
- GPUs : 256
- Simulation (h) : 100
- Initial height (m) : 10.0

Initial state of each objects



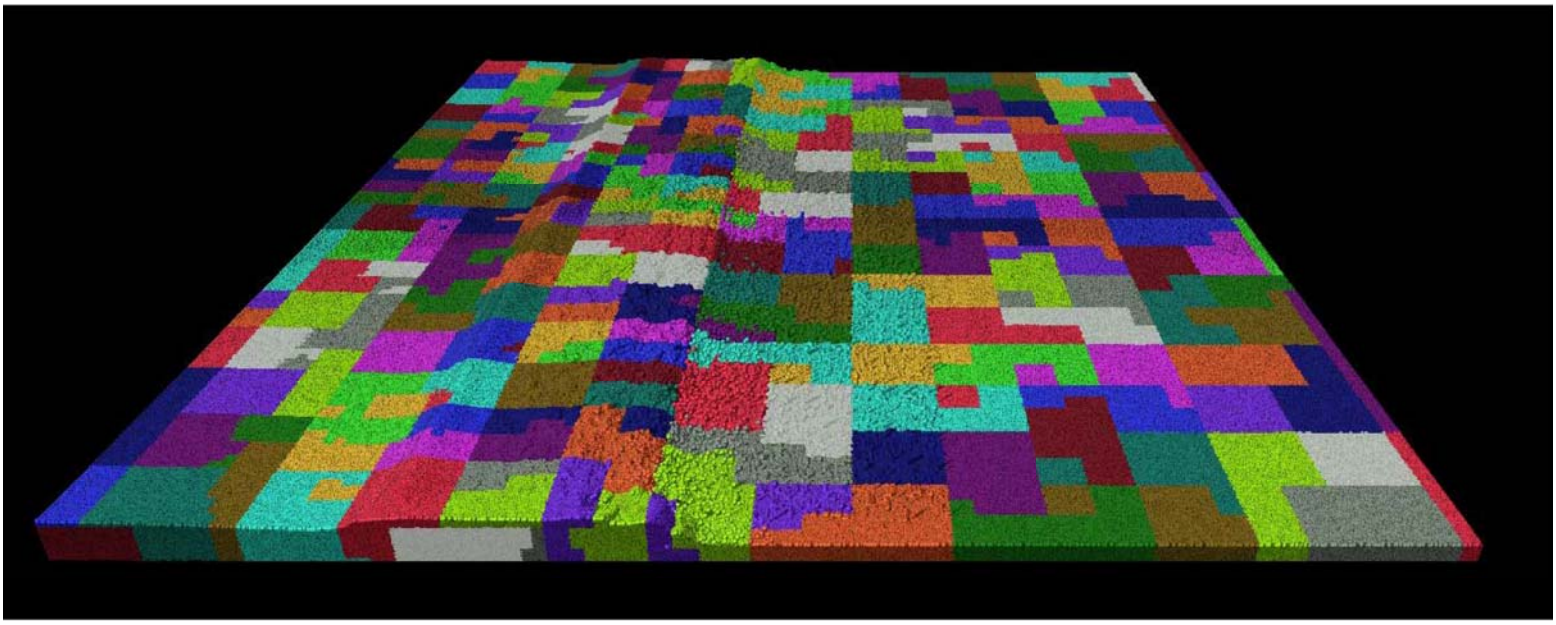
Representation of object shapes

CAD Data　　Particles



Dynamic Domain Decomposition

- Using the improved SPH with 87Million particles with 256 GPUs



東京都心部の10km四方の1m格子解像度による大規模気流シミュレーション

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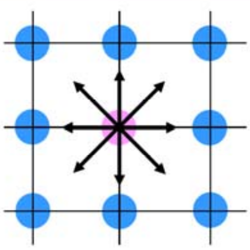
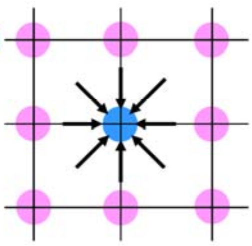
LBM (Lattice Boltzmann Method)

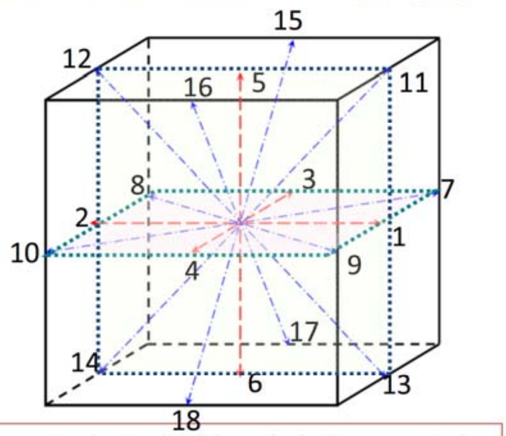
$$\frac{\partial f_i}{\partial t} + \mathbf{e}_i \cdot \nabla f_i = -\frac{1}{\lambda}\left(f_i - f_i^{eq}\right)$$

Streaming step:



Collision step:





SRT: Memory Bound, MRT: Compute Intensive

$$f_i^{eq} = \rho w_i \left[1 + \frac{3}{c^2}(\mathbf{e}_i \cdot \mathbf{u}) + \frac{9}{2c^4}(\mathbf{e}_i \cdot \mathbf{u})^2 - \frac{3}{2c^2}(\mathbf{u}\cdot\mathbf{u})\right]$$

$\boldsymbol{i}$ is the value in the direction of *ith* discrete velocity
e_i is the discrete velocity set;
w_i is the weighting factor
$\mathbf{u}$ is the macroscopic velocity

$$f_\alpha(\boldsymbol{x} + \boldsymbol{c_i}\Delta t, t + \Delta t) - f_\alpha(\boldsymbol{x}, t) = -M^{-1}_{\alpha\beta}\hat{S}_{\beta\beta'}M_{\beta'\alpha'}\left(f_{\alpha'}(\boldsymbol{x}, t) - f^{eq}_{\alpha'}(\boldsymbol{x}, t)\right)$$

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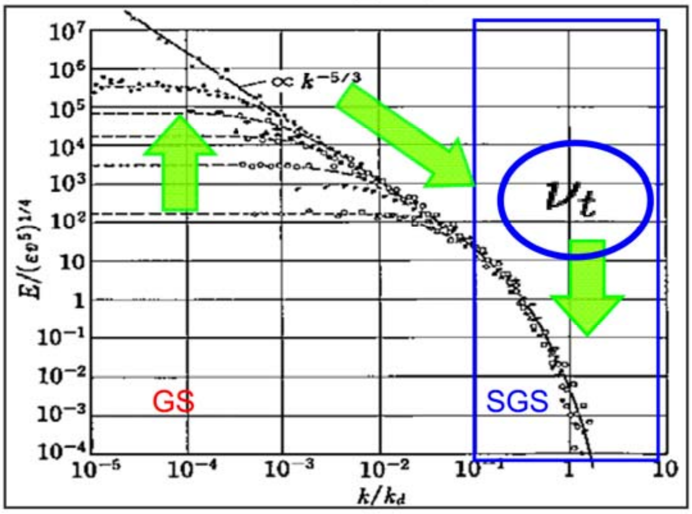
LES (Large-Eddy Simulation)

$$f_i(x - c_i\Delta t, t + \Delta t) = f_i(x,t) - \frac{1}{\tau_*}(f_i(x,t) - f_i^{eq}(x,t)) + F_i$$

Energy spectrum



Relaxation time for LES model

$$\tau_* = \frac{1}{2} + \frac{3\nu_*}{c^2\Delta t}$$

$$\nu_* = \nu_0 + \nu_t$$

Molecular viscosity and Eddy viscosity

コヒーレント構造スマゴリンスキーモデル

Computational Area

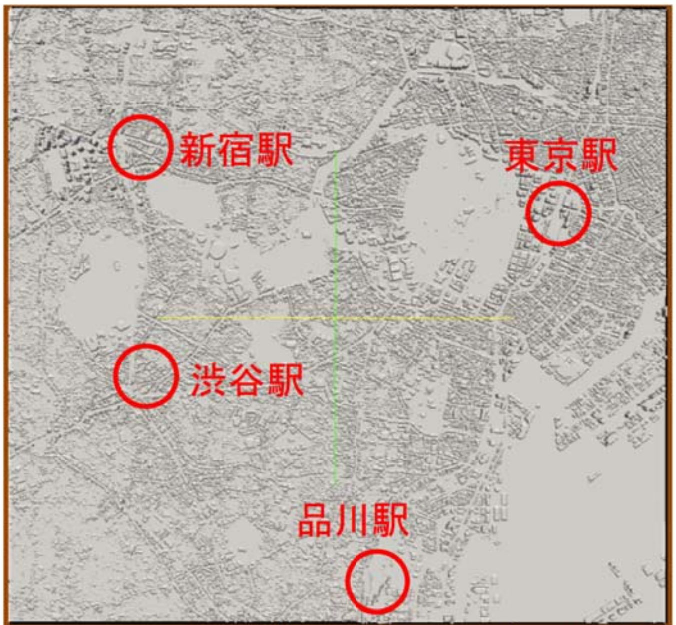
Major part of Tokyo

Including Shnjuku-ku, Chiyoda-ku, Minato-ku, Meguro-ku, Chuou-ku,

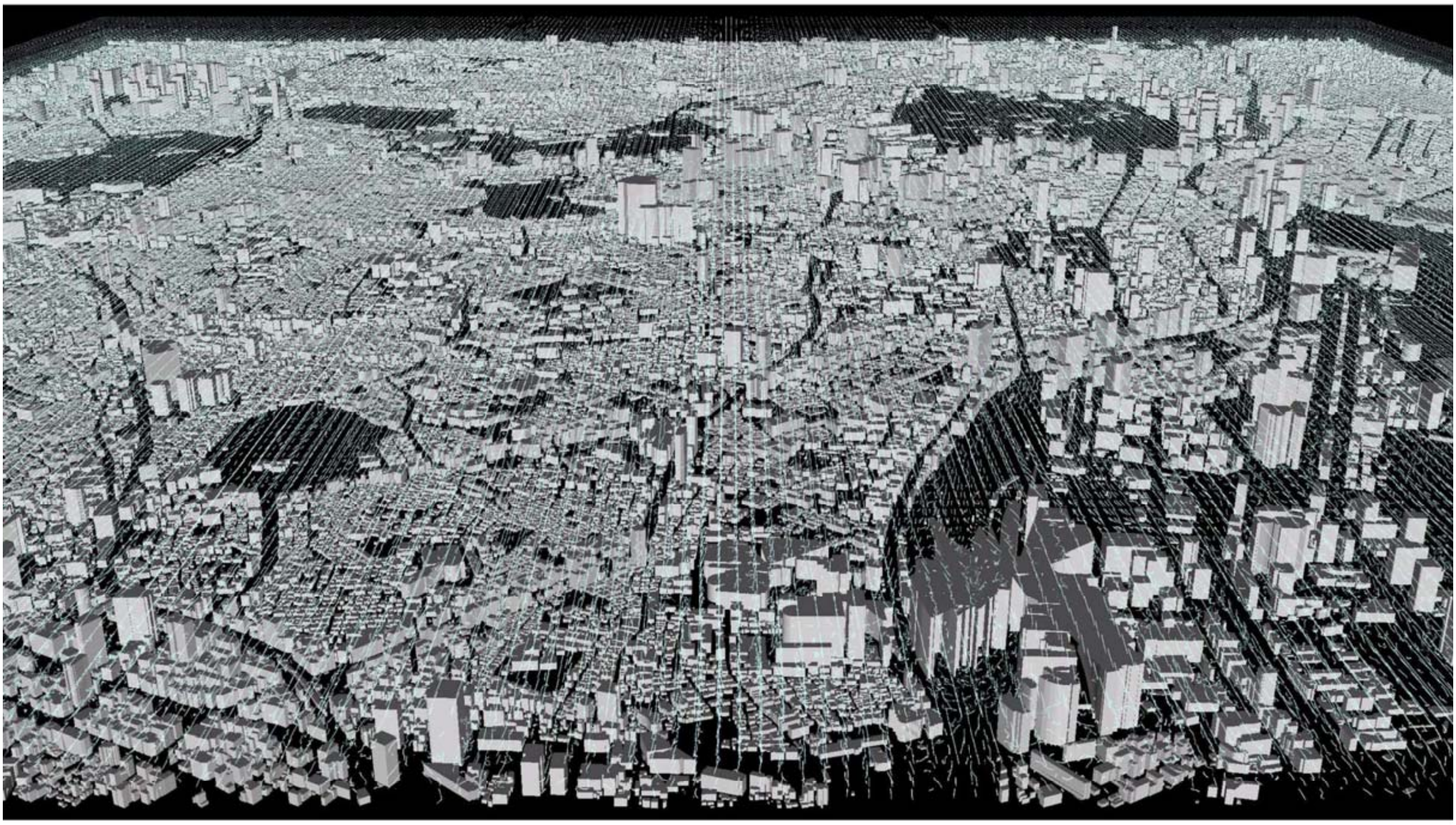
10km×10km

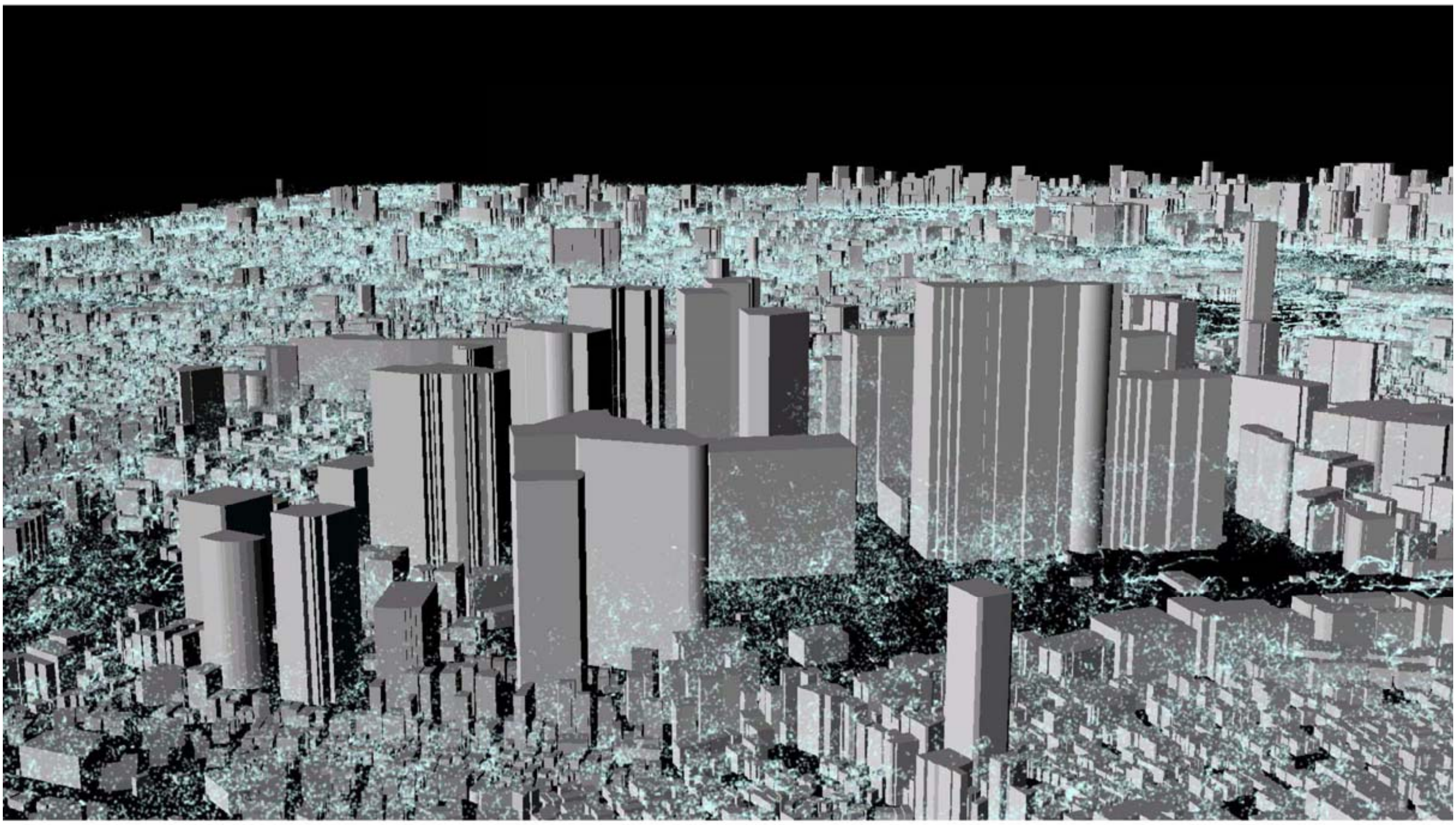
Building Data:

Pasco Co. Ltd.
TDM 3D



Map ©2012 Google, ZENRIN

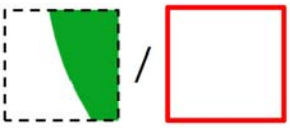




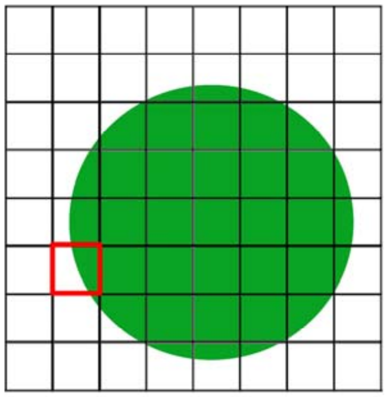
LBM-DEM coupled method

- Solid fraction in each cell: β_n
- Bounce back boundary condition $\boldsymbol{f}^m$

$$\boldsymbol{f}(\boldsymbol{x}+\boldsymbol{c}_i\Delta t, t+\Delta t) = \boldsymbol{f}(\boldsymbol{x},t) - (\boldsymbol{I}-\boldsymbol{\beta})\boldsymbol{M}^{-1}\boldsymbol{S}\big(\boldsymbol{m}(\boldsymbol{x},t) - \boldsymbol{m}^{eq}(\boldsymbol{x},t)\big) + \boldsymbol{\beta}\boldsymbol{f}^m$$

$\beta_n =$ 

$\boldsymbol{\beta}$: β_n *diagonal matrix*

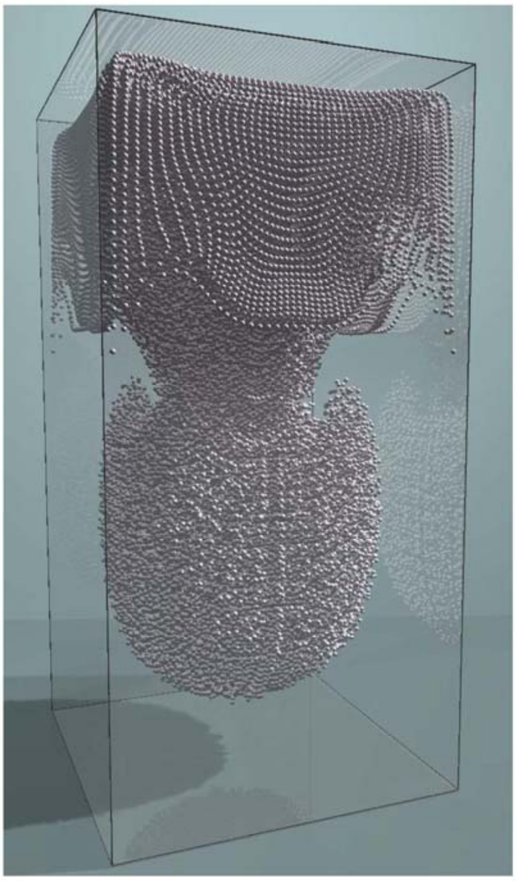


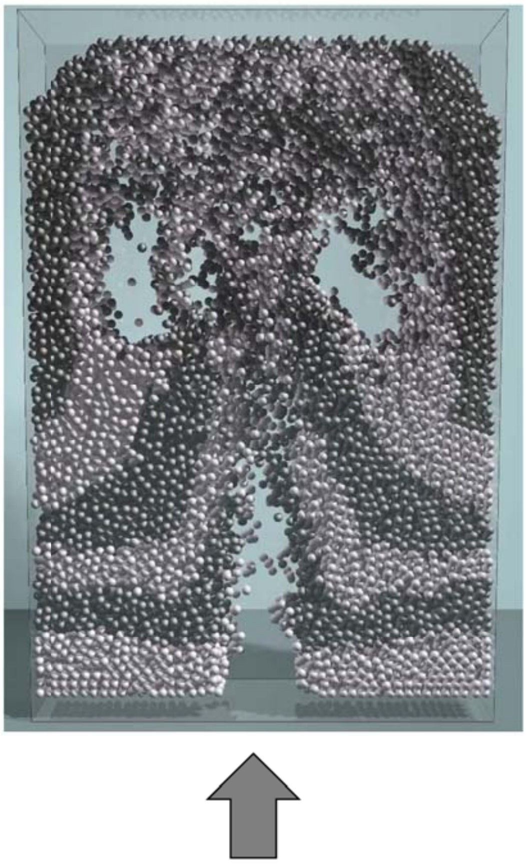
$$f_i^m = \left[f_{-i}(\boldsymbol{x},t) - f_{-i}^{\mathrm{eq}}(\rho,\boldsymbol{u})\right] - \left[f_i(\boldsymbol{x},t) - f_i^{\mathrm{eq}}(\rho,\boldsymbol{v}_{\mathrm{wall}})\right]$$

$$\boldsymbol{v}_{\mathrm{wall}} = \boldsymbol{v}_{\mathrm{particle}} + \boldsymbol{\omega}_{\mathrm{particle}} \times \left(\boldsymbol{x} + \frac{\boldsymbol{c}_i\Delta t}{2} - \boldsymbol{x}_{\mathrm{particle}}\right)$$

DEM
68,921 particles

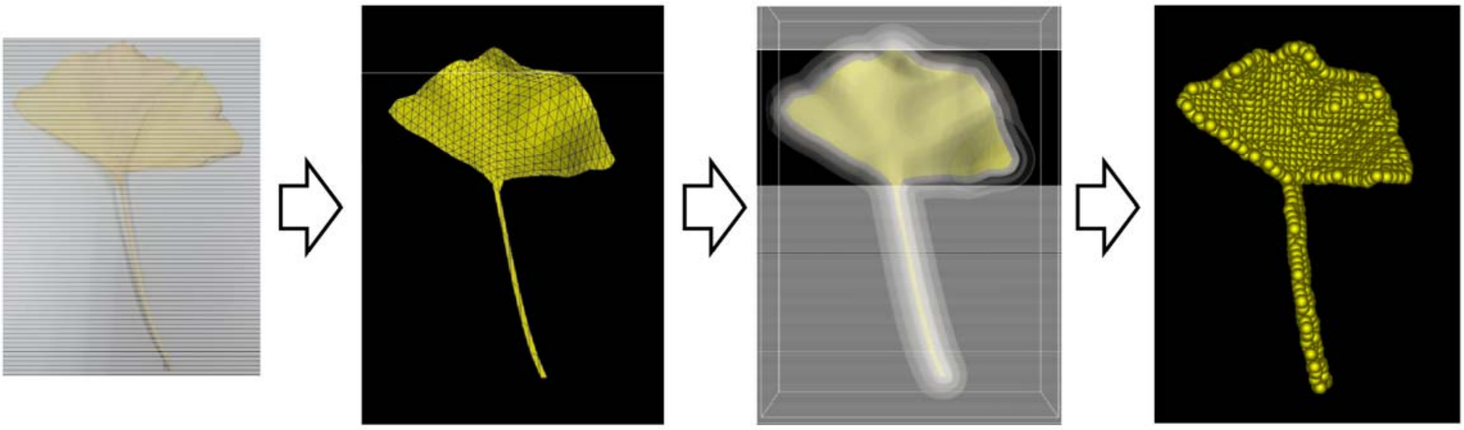
LBM
288x288x576 mesh





Falling Gingko leaves

Modeling of Gingko leaf



Real | Polygons | Level Set | Particles (Collision detection)

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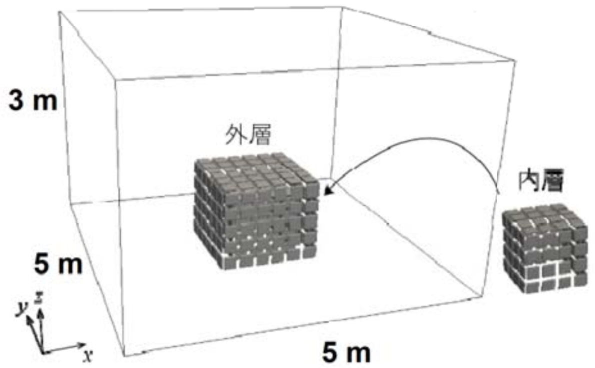
爆風飛散シミュレーション

Compressible Fluid

$$\frac{\partial \boldsymbol{U}}{\partial t}+\frac{\partial \boldsymbol{F}}{\partial x}+\frac{\partial \boldsymbol{G}}{\partial y}+\frac{\partial \boldsymbol{H}}{\partial z}=\frac{\partial \boldsymbol{F}_v}{\partial x}+\frac{\partial \boldsymbol{G}_v}{\partial y}+\frac{\partial \boldsymbol{H}_v}{\partial z}$$

$$\boldsymbol{U}=\begin{bmatrix}\rho\\ \rho u\\ \rho v\\ \rho w\\ \rho e\end{bmatrix}\quad \boldsymbol{F}=\begin{bmatrix}\rho u\\ \rho u^2+p\\ \rho vu\\ \rho wu\\ u(\rho e+p)\end{bmatrix}\quad \boldsymbol{G}=\begin{bmatrix}\rho v\\ \rho uv\\ \rho v^2+p\\ \rho wv\\ v(\rho e+p)\end{bmatrix}\quad \boldsymbol{H}=\begin{bmatrix}\rho w\\ \rho uw\\ \rho vw\\ \rho w^2+p\\ w(\rho e+p)\end{bmatrix}$$

Immersed Boundary Method



内側に TNT 1kg

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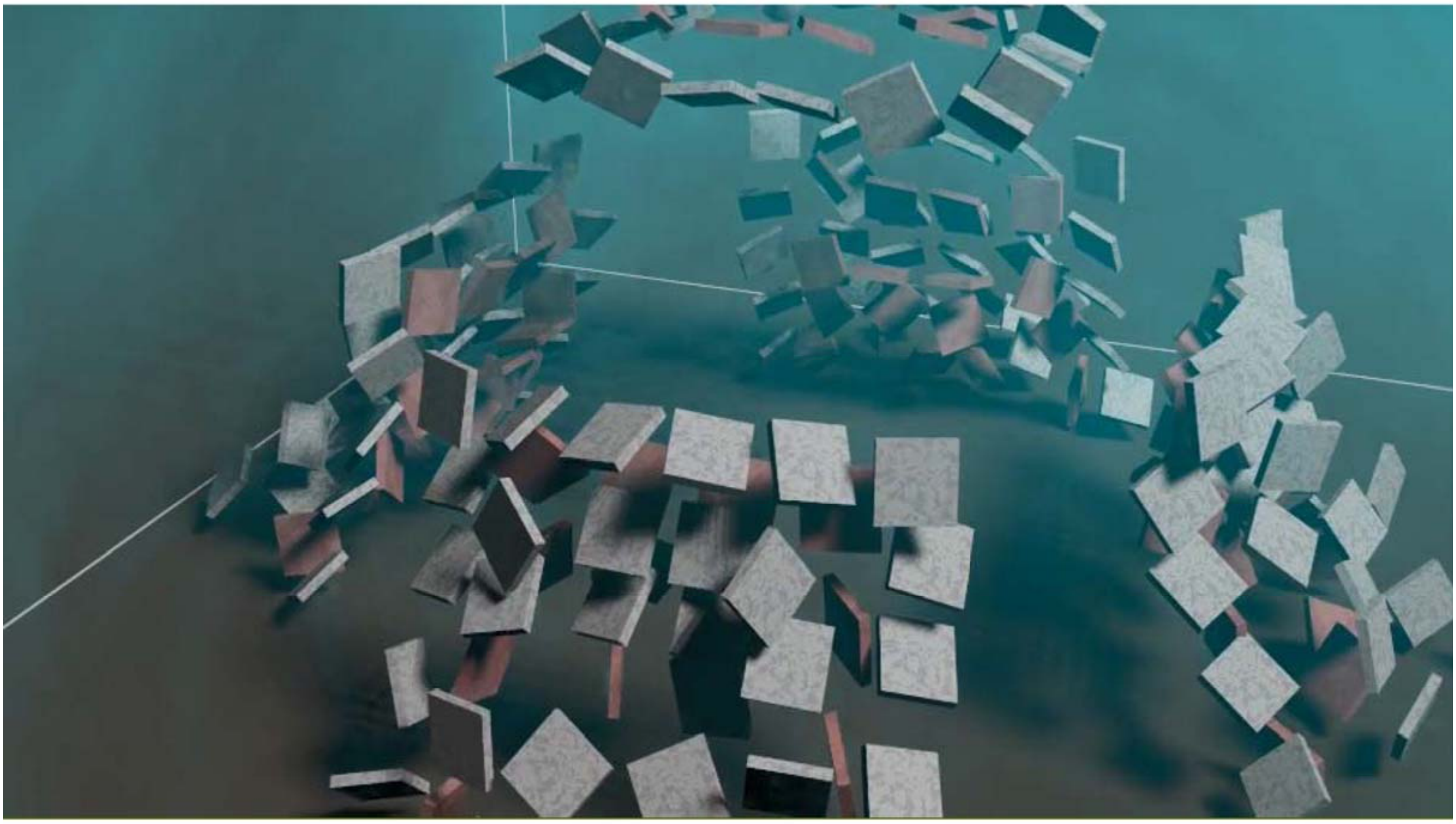
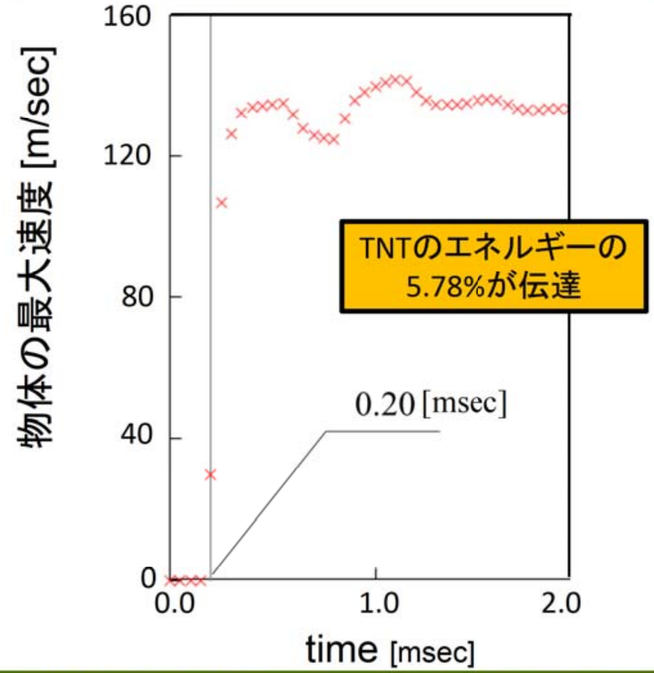
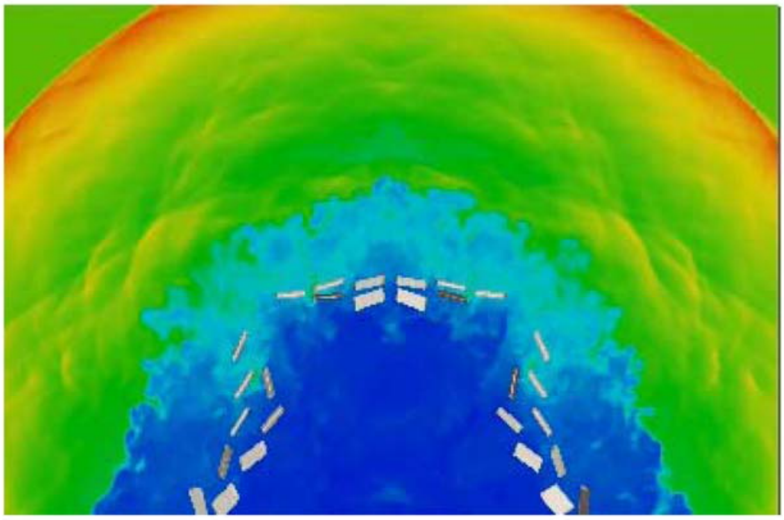


飛散挙動



物体の加速開始



スパコンからのイノベーション

東京工業大学 学術国際情報センター 共同利用推進室

学外利用に供するTSUBAMEの資源量の推移

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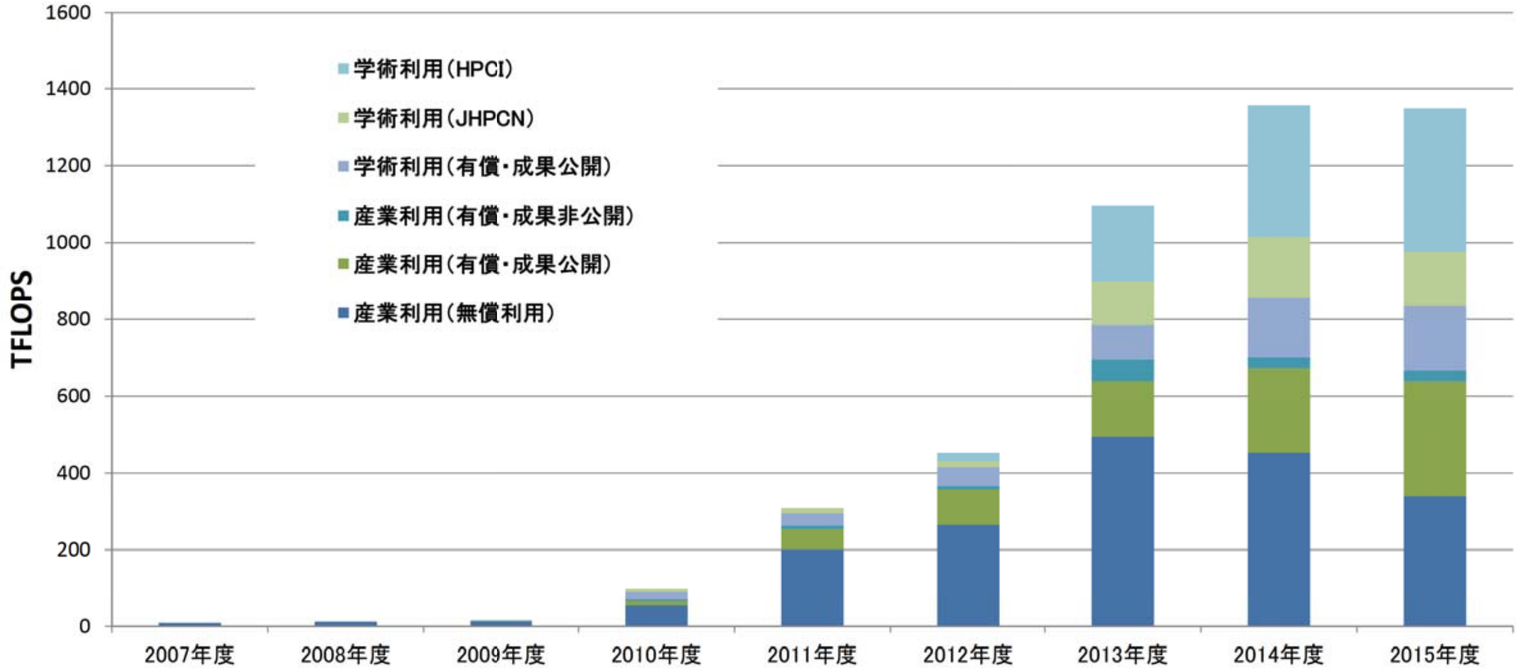

東京工業大学　学術国際情報センター

TSUBAME利用種別利用ノード時間積割合（2015年度実績）

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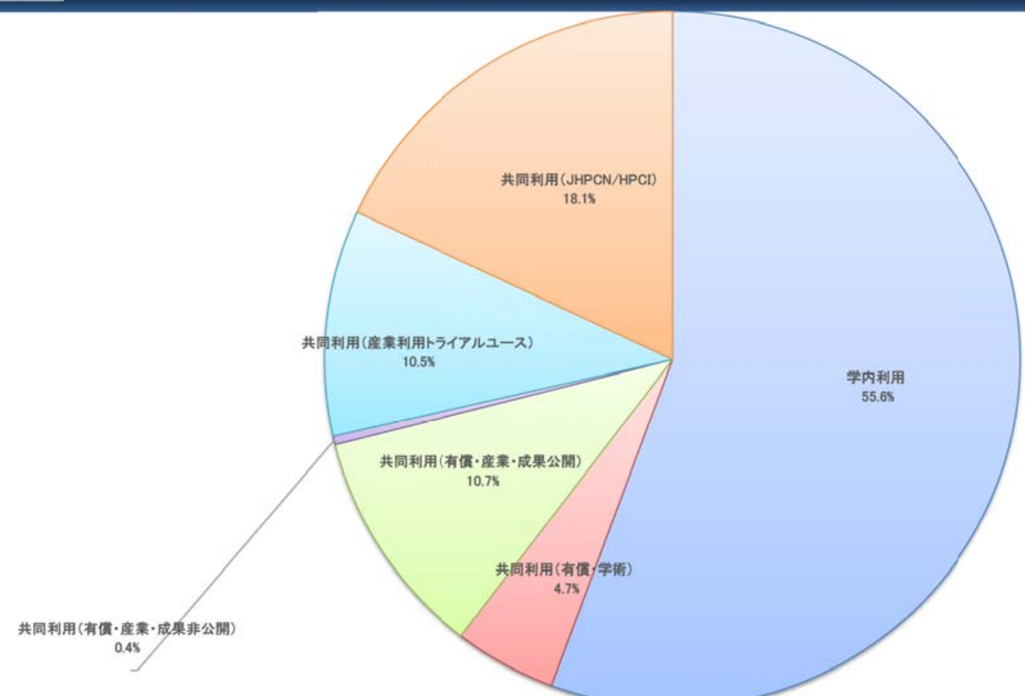
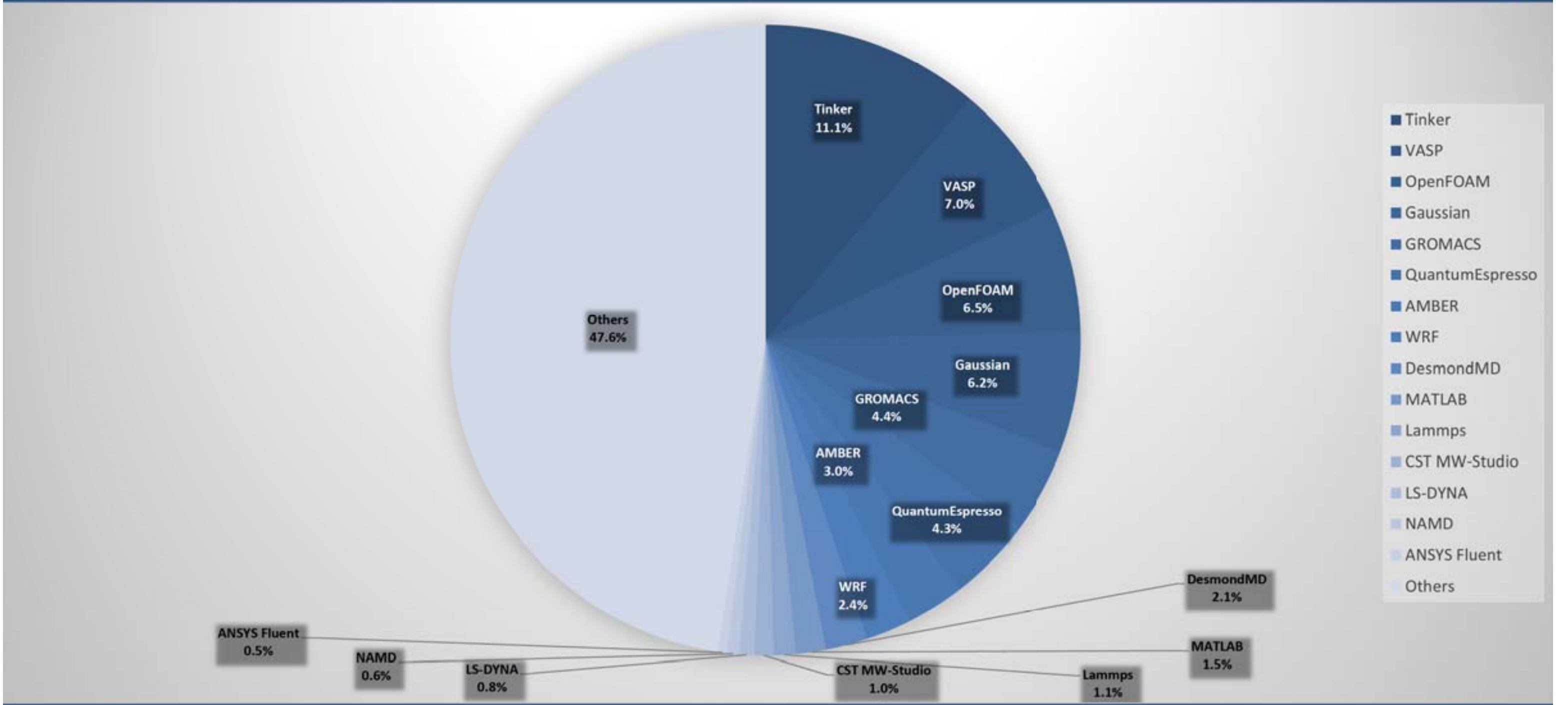
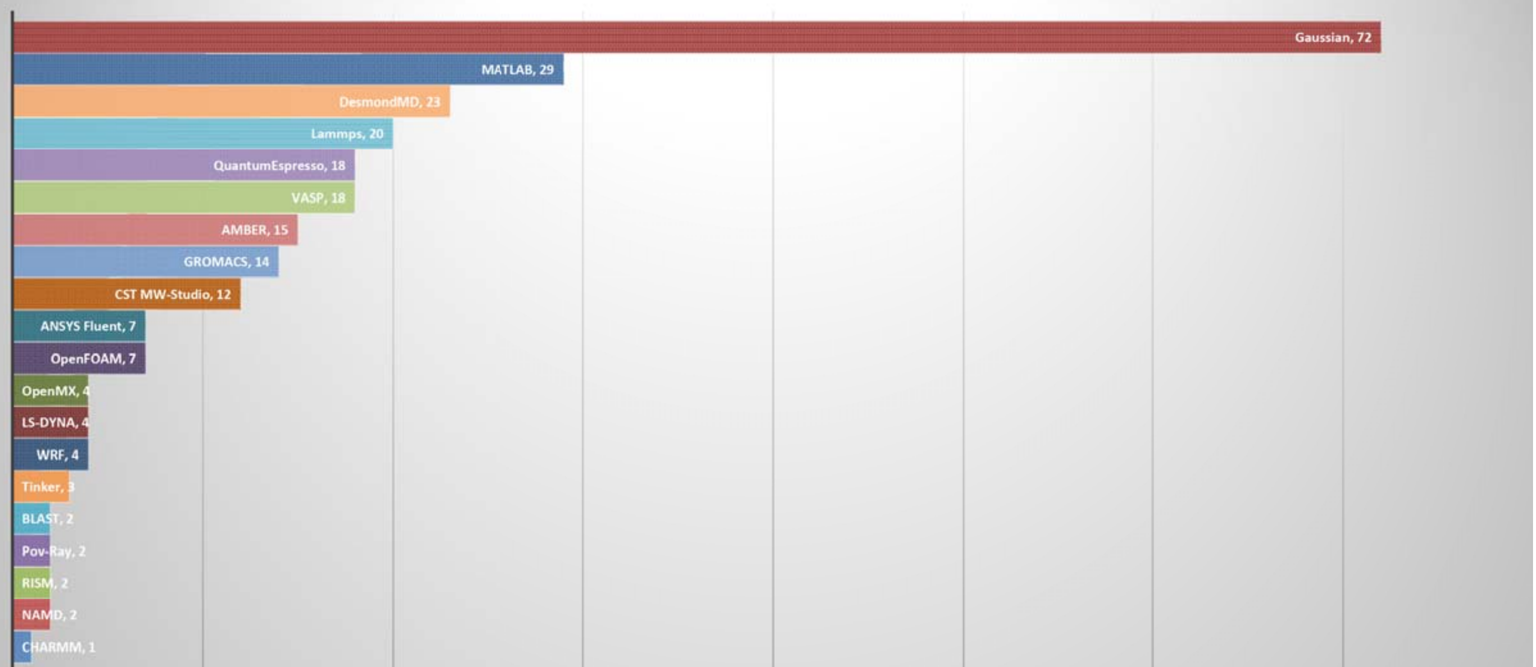


東京工業大学　学術国際情報センター

アプリケーション別利用ノード時間積割合（2015年12月実績）



アプリケーション別利用ユーザ数（2015年12月実績）



TOTO株式会社様の事例

利用企業:
TOTO株式会社 技術開発センター
利用課題名:
衛生陶器設計のための並列GPGPU気液二相流シミュレーション
課題区分:
トライアルユース（戦略分野:アクセラレータ利用技術の推進）
利用期間:
平成23年10月～トライアルユース継続利用中
解析プログラム:
自社開発プログラム（GPU化も自社で実施）
可視化プログラム:
POV-Ray（TSUBAME上で可視化）
使用目的:
大容量高精細な格子により高精度なシミュレーションを実現
従来の1/3の格子　解像度として81倍
成果
約1.5億格子の解析において、100GPUで80倍以上の速度向上、150GPUで100倍の速度向上

衛生陶器シミュレーション

TSUBAMEでの解析結果

自社のクラスタでの解析結果

シミュレーション結果の精度検証

1.5mm /mesh
(従来: 自社クラスタ)

0.5mm /mesh
(TSUBAME)

実機流れ

GP GPU

最 後 に

スパコンは計算資源や解析ツールを提供するだけです。

イノベーションを起こすのは、**利用者の方々です。**

Thank you

