HPCAsia Post127

Acoustic simulation using lattice Boltzmann method by multi-GPU parallel computing

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1. Backgrounds: Acoustic analysis

- Various analysis methods are used for acoustic analysis.
  FDTD method, FEM, CIP, etc.
- Conventional methods have problems in the following points.
  - Calculation accuracy
  - Computational time
  - Various boundaries (Vibrating boundary, Complex boundary)

In acoustic analysis, as the vibration frequency increases, the grid size needs to be further reduced, which increases the computational scale.

2. Proposed method

Combining the following three methods.

1. Lattice Boltzmann method - Calculation accuracy
2. Immersed Boundary method - Various boundaries
3. Parallel Computing with multi-GPU - Computational time

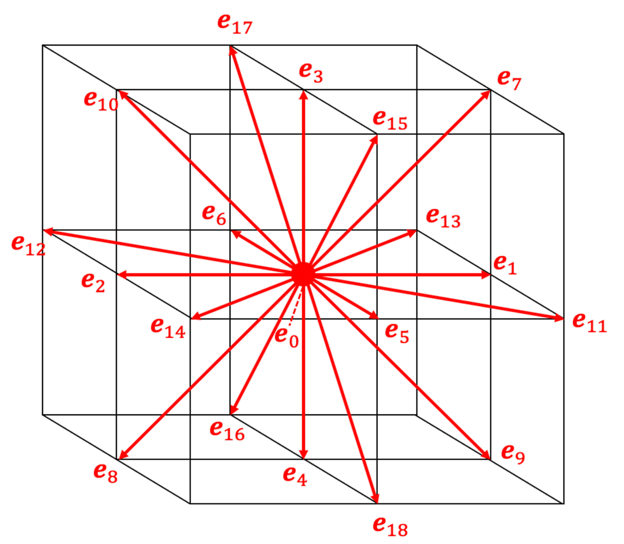
3. Lattice Boltzmann method

The lattice Boltzmann method has been proposed as an analysis method for fluid dynamics, it can be applied to acoustic analysis by using the acoustic time scale, which deal with the fast phenomenon of moving virtual particles. In that case, the speed of sound is equal to the speed at which the virtual particle moves through the lattice ($\boldsymbol{e_i}$).

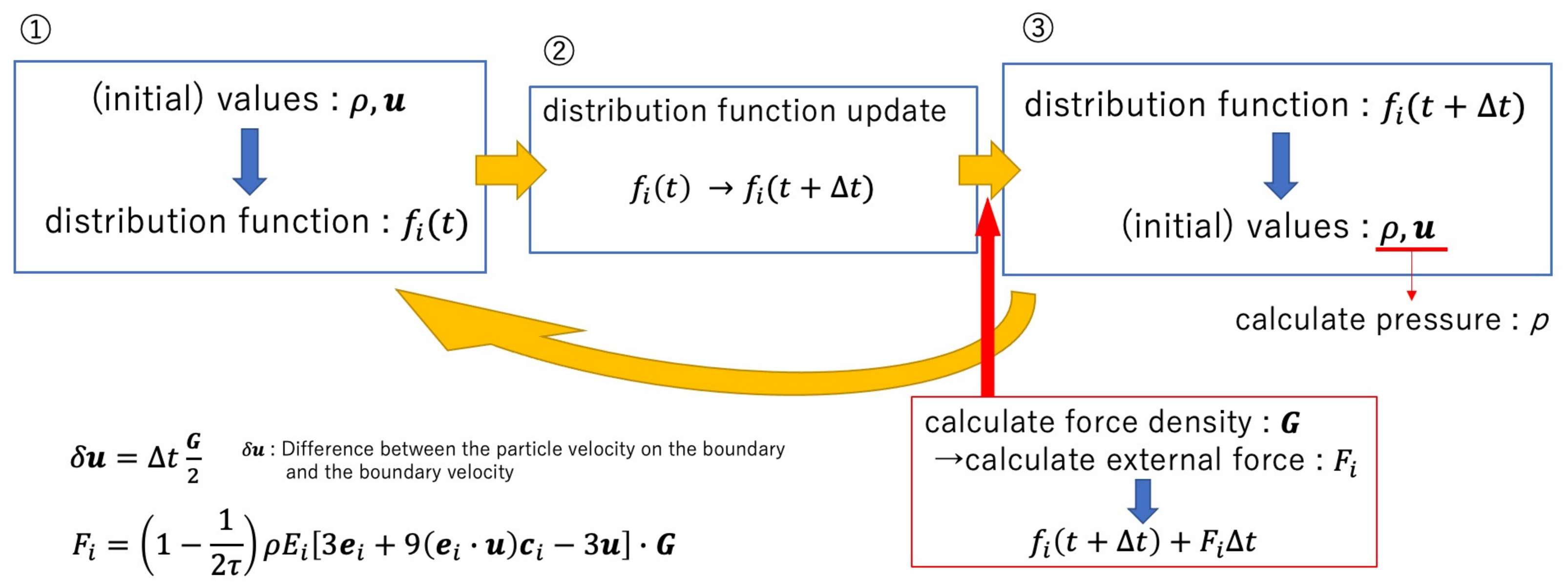
① $$f_i^{eq} = E_i \rho \left[1 + 3\boldsymbol{e}_i \cdot \boldsymbol{u} + \frac{9}{2}(\boldsymbol{e}_i \cdot \boldsymbol{u})^2 - \frac{3}{2}\boldsymbol{u} \cdot \boldsymbol{u}\right]$$

② $$f_i(\boldsymbol{x} + \boldsymbol{e}_i \Delta x, t + \Delta t) = f_i(\boldsymbol{x}, t) - \frac{1}{\tau}\left[f_i(\boldsymbol{x}, t) - f_i^{eq}(\boldsymbol{x}, t)\right]$$

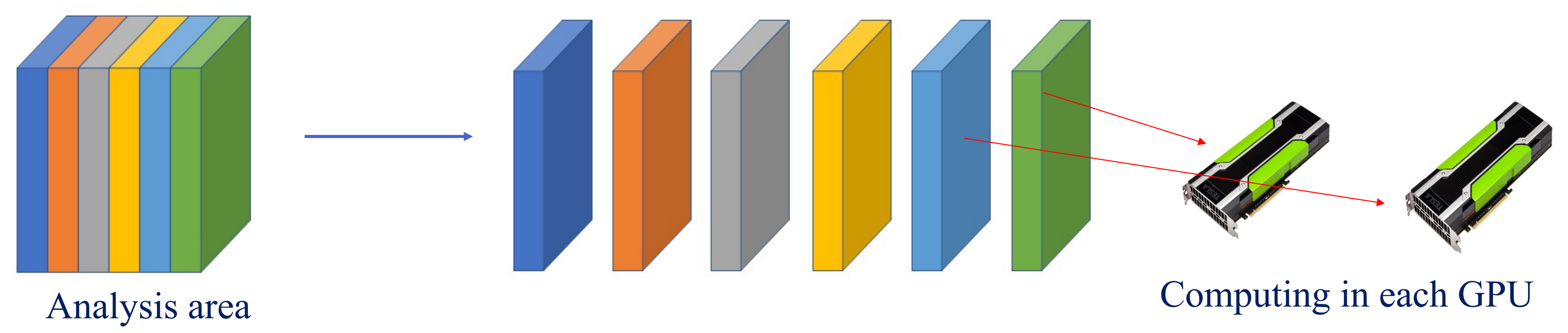
③ $$\sum_{i=1}^{N} f_i = \rho \qquad \frac{1}{\rho}\sum_{i=1}^{N} \boldsymbol{e}_i f_i = \boldsymbol{u}$$



4. Application of immersed boundary method to LBM

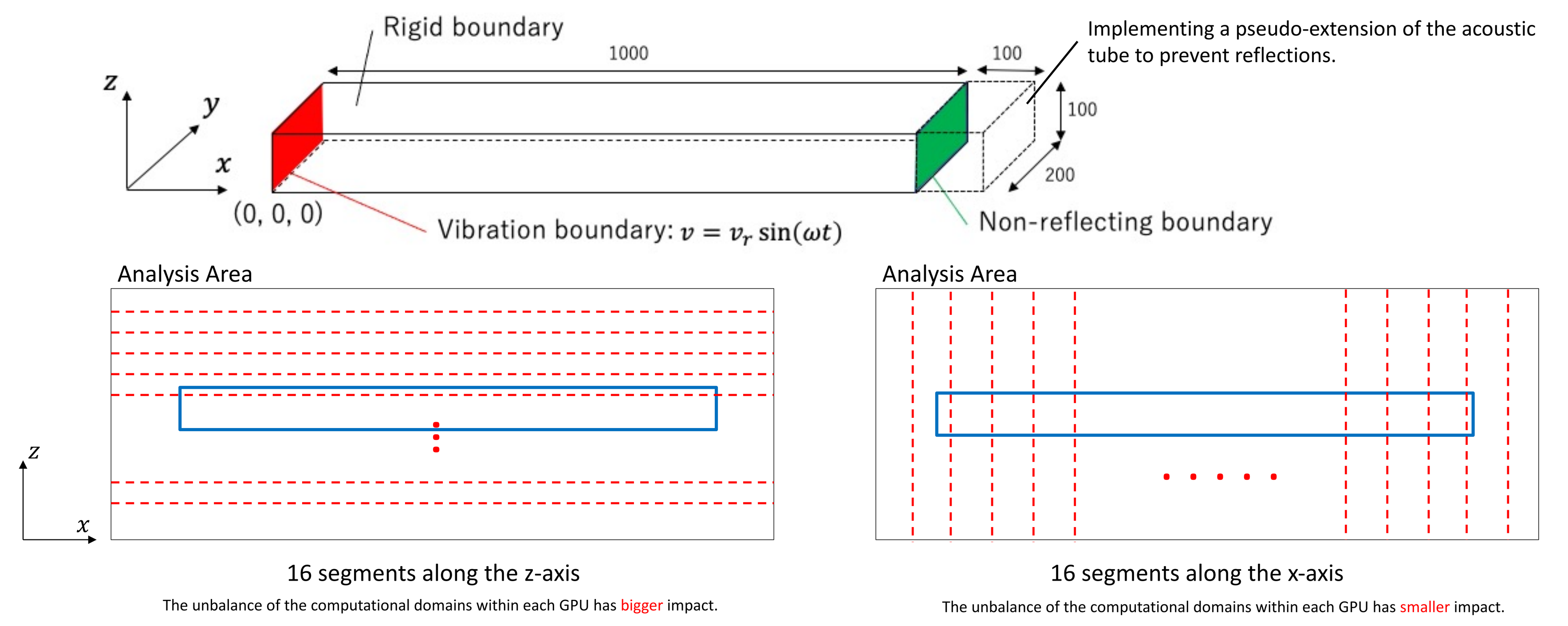


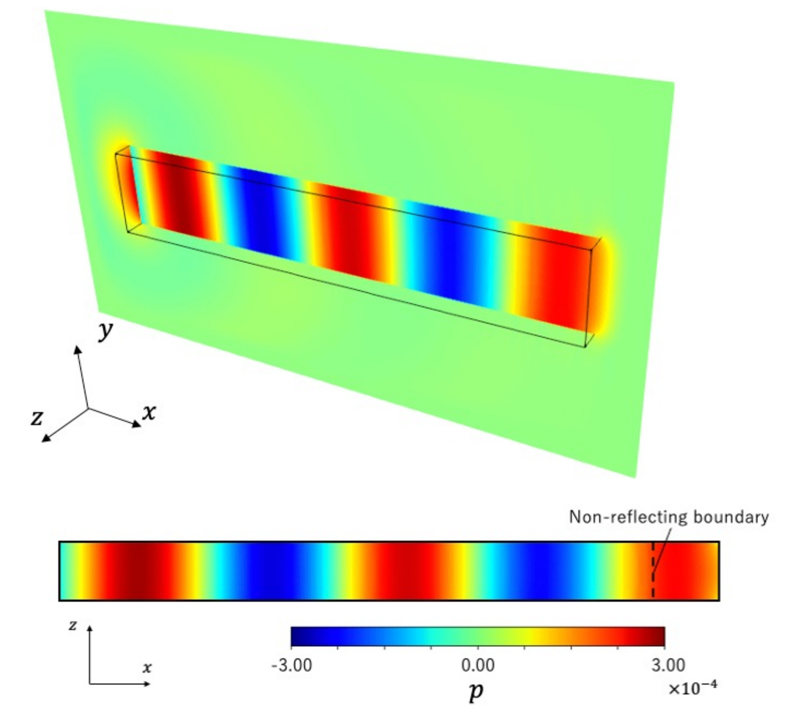
5. Parallel computing with multi-GPU



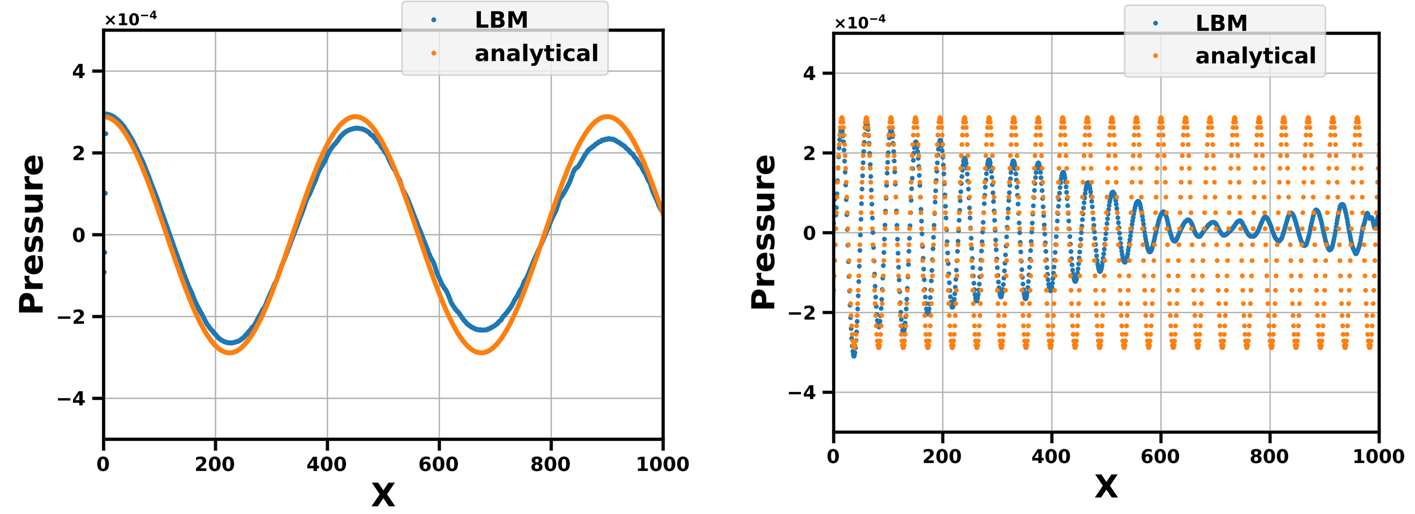
- This makes it possible to reduce Computational time.
- Some data on boundary must be passed between GPUs.
- Computation of the immersed boundary method is done in the region where it exists.

6. Analysis results





- Grid size and Calculation accuracy



Acoustic contours along the x-axis inside the acoustic tube at each frequency.

We need higher resolution to analyze high frequency.

- Segments along the z-axis or x-axis

	Calculation time in IBM (1 timestep)	The total number of grid points on IBM in each region	The largest number of grid points in each region
Segment along the z-axis	0.435 [sec]	1.4×10^6	4.8×10^5
Segment along the x-axis	0.401 [sec]	1.4×10^6	1.3×10^5

The bottleneck is the region with the largest number of grid points on the immersed boundary.

7. Summary

- In high-frequency analysis, unexpected wave interference and other problems occur, and the resolution of the grid must be matched to the analysis frequency.
- When the analysis domain is divided by multi-GPU, if the immersed boundary is stuck in one part, that part becomes the bottleneck of the analysis. Therefore, in the future, it may be necessary to divide the analysis area considering the number of grid points on the immersed boundary by using the AMR method.