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A 3-D Numerical Simulation by the Continuous-velocity Lattice-gas Model

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1 Background and Purpose

There are a finite difference method and a finite element method as a means to elucidate a past fluid phenomenon. It is necessary that these display first the real flow by the expression of the formulation, that is, differential equation etc.The control equation is made from the use of a variety of approximation methods to make the problem easily, and the phenomenon is elucidated by replacing this with the algebra equation by an appropriate numeric method, and making calculation on the computer. Therefore, these methods have the meaning with a very important expression model by which the flow is shown.

The continuous-velocity lattice-gas model is a method to which the lattice gas model is enhanced. These are the methods to which the flow is delimited with a regular lattice, a virtual particle is made to move, and the flow of the entire faction is elucidated by pursuing those movements. Therefore, the control equation by which the system is shown elucidates the flow by deciding the boundary condition and the collision rule which acts directly on the particle without the necessity. From micro level to difference from analyzed technique numerical value from macro standpoint, and analytical technique of non-compressed flow is analyzed of fluid phenomenon.

The lattice-gas model does not have the particle with the same speed on the same lattice. Therefore, it is necessary to do special consideration to the collision rule of the particle, and there is a problem of should the use of a complex lattice because of the asymmetry of the lattice in three dimensions. The continuous-velocity lattice-gas model is an analytical method of non-compressed flow advocated by Mr. A.Malevanets in 1997. This method differs from a past lattice gas method, and has the speed of the particle in the real number value. As a result, because a necessary exclusive rule in a past method is not necessary, this method can have the number of particles without the limitation.

Moreover, the temperature can be given as a speed of the particle, and a energy equation is not necessary in this method in a past analytical method in the heat flow. In a word, special consideration is not needed even when calculating with heat flow.

Moreover, the amount of the movement of all particles which exist on the same lattice point is described as for the collision process by a single operation of rotating by the turn of the center of gravity. Moreover, the square grid is used in two dimensions for the calculation. It is thought that these are a suitable calculation methods for a three-dimensional calculation.

The calculation time grows as growing of the calculation area for this technique to calculate some virtual each one of the particle on the lattice point and the density of the particle grow. Therefore, the method becomes a problem with a big increase of the calculation time when enhancing to a three-dimensional calculation. However, the movement and the collision of the particle can be calculated all together in the system. Therefore, it is thought that this method is fundamentally suitable for a parallel calculation. As a result, it can be thought that the calculation time can be shortened by the paralle computing.

However, the study by which a concrete, parallel calculation of three dimensions by this technique is treated has not been performed yet. Then, a three-dimensional model is developed by the continuous-velocity lattice-gas model in this text. In that case, I think about a parallel algorithm suitable for the continuous-velocity lattice-gas model. And, a numeric simulation and the consideration were done.

2 simulation

A three-dimensional model based on the continuous-velocity lattice-gas model was developed, it was mounted on the computer, and the couette flow and the cavity flow were calculated. In the couette flow, the result of obtaining was corresponding to an analytical solution well. As a result, it was confirmed that the cycle boundary condition was useful. Moreover, it has been understood to approach an analytical solution by raising the number of lattices and the number of particles densities.

Moreover, because the Reynolds number was few in the cavity flow, a quantitative evaluation was not able to be done. However, it was confirmed to satisfy from the figure of velocity profile and the figure of streamline qualitatively. Moreover, it was able to be confirmed to approach qualitatively by increasing the number of lattices.

It is necessary to increase the number of lattices to calculate a bigger Reynolds number because do the proportion of the Reynolds number to the number of lattices in this method. Moreover, when the number of lattices and the numbers of particles grow, accuracy improves from the previous experiment. However, when the number of lattices is increased, the calculation time's growing becomes a problem.

3 Parallel Computing

Then, the decrease of the calculation time was attempted by the parallel computing. The particle was evenly divided with the lattice, and the lattice do not divided. This was mounted on CRAY T3E, the calculation time was measured, and the speed-up ratio was obtained. As a result, it has been understood to be able to enlarge the speed-up ratio in the model with large number of lattices and densities. Moreover, in measuring the communication time, it has been understood that the speed-up ratio does not go up because the proportion of the network time to the execution time increases as for this method. Then, it was tried to decrease the network time by decreasing the amount of the trafic. However, the network time increases by the communication frequency's increasing though the amount of the communication can be decreased in the try method. Therefore, it has been understood that the first method is the most efficient.

4 Problem

The problem in the future be to be able to develop a better, parallel algorithm from the viewpoint by which the communication time is decreased, and to calculate a big model of the Reynolds number. And, the continuous-velocity lattice-gas model has the advantage that heat flow can be easily handled compared with a past method as previously described. Therefore, this advantage is made the best use of and calculation with heat flow using continuous-velocity lattice-gas method.