DEVICE, METHOD AND COMPUTER PROGRAM FOR PERFORMING LBM-BASED IMMISCIBLE MULTICOMPONENT FLUID ANALYSIS SIMULATION

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit under 35 USC 119(a) of Korean Patent Applications No. 10-2022-0158389 filed on November 23, 2022 in the Korean Intellectual Property Office, the entire disclosures of which are incorporated herein by reference for all purposes.

TECHNICAL FIELD

[0001] The present disclosure relates to a device, a method, and a computer program for performing a lattice Boltzmann method (LBM)-based immiscible multicomponent fluid analysis simulation.

BACKGROUND

[0002] Computational fluid dynamics (CFD) as a field of fluid dynamics calculates a dynamic motion of a fluid using a computer in a numerical analytical method. The CFD calculates the flow of the fluid by discretizing a Naiver-Stokes Equation which is a partial differential equation through methods such as Finite Difference Method (FDM), Finite Element Method (FEM), Finite Volume Method (FVM), and Smoothed Particle Hydrodynamics (SPH).

[0003] The Navier-Stokes equation may be calculated by a lattice-based method that discretizes a spatial domain into a small spatial mesh or lattice, or a particle-based method that expresses a fluid as a set of particles.

[0004] In the particle-based method, a more natural simulation of natural or physical phenomena is possible by expressing an analysis target as particles instead of using a lattice. The

particle-based method includes Smoothed Particle Hydrodynamics (SPH), Moving Particle Semi-implicit (MPS), Lattice Boltzmann Method (LBM), etc.

[0005] The LBM-based fluid analysis predicts a motion using probability distribution functions of virtual particles on a lattice (grid). The LBM-based fluid analysis can produce accurate results while reducing a calculation amount even when the scale of the system is increased. In particular, the LBM-based fluid analysis can relatively easily analyze a complicated boundary or a multiphase flow.

[0006] However, in an analysis of an LBM-based immiscible multiphase or multicomponent fluid, accurate and efficient tracking of an interface is highly complicated, and the analysis requires a large calculation time and a long analysis time for application to various phenomena and technical fields.

PRIOR ART DOCUMENT

[0007] [Patent Document]

Patent Document 1: Korean Patent No. 10-2200443 B1 (registered on January 4, 2021)

SUMMARY

[0008] In view of the foregoing, the present disclosure provides a fluid analysis simulation including receiving data about an immiscible multicomponent fluid, which is an analysis target, generating a calculation lattice system for calculating fluid component data and flow data, and calculating the entire flow field while tracking an interface of the multicomponent fluid.

[0009] Further, the present disclosure provides a device, a method, and a computer program for performing a fluid analysis simulation that can calculate an interface of a multicomponent fluid and a flow fluid in efficient amounts, respectively.

[0010] Furthermore, the present disclosure provides a device, a method, and a computer program for performing a fluid analysis simulation that can stably analyze an interface of a multicomponent fluid by assigning a continuous physical value to the interface.

[0011] The problems to be solved by the present disclosure are not limited to the above-described problems. There may be other problems to be solved by the present disclosure.

[0012] As a means for solving the problems, according to an aspect of the present disclosure, a fluid analysis simulation device based on a lattice Boltzmann method (LBM) includes an input unit configured to receive data about an analysis target including a first fluid and a second fluid; a lattice generator configured to generate a calculation lattice system to calculate fluid component data and flow data and an output lattice system to output an analysis result based on the received data; a data calculator configured to calculate fluid component data and flow data of the analysis target based on the calculation lattice system; and a simulator configured to perform the fluid analysis simulation based on the output lattice system. The data calculator calculates fluid component data of an interface between the first fluid and the second fluid based on a first governing equation, and flow data of flow fields of the first fluid and the second fluid based on a second governing equation.

[0013] The calculation lattice system includes a first calculation lattice model configured to calculate fluid component data based on the first governing equation; and a second calculation lattice model configured to calculate flow data based on the second governing equation and having a greater number of vectors than the first calculation lattice model.

[0014] The data calculator calculates fluid component data and flow data in order for at least one physical value to be continuously changed at the interface between the first fluid and the second fluid.

[0015] According to another aspect of the present disclosure, a fluid analysis simulation method based on a lattice Boltzmann method (LBM) includes receiving data about an analysis target including a first fluid and a second fluid; generating a calculation lattice system to calculate fluid

component data and flow data based on the received data; generating an output lattice system to output an analysis result; calculating fluid component data and flow data of the analysis target based on the calculation lattice system; and performing the fluid analysis simulation based on the output lattice system. In calculating fluid component data and flow data includes calculating fluid component data of an interface between the first fluid and the second fluid based on a first governing equation, and calculating flow data of flow fields of the first fluid and the second fluid, respectively, based on a second governing equation.

[0016] The above-described aspects are provided by way of illustration only and should not be construed as liming the present disclosure. Besides the above-described embodiments, there may be additional embodiments described in the accompanying drawings and the detailed description.

[0017] According to the present disclosure, it is possible to effectively calculate an interface of a multicomponent fluid and the entire flow field of an immiscible multicomponent fluid based on a first governing equation and a second governing equation, respectively. Therefore, the fluid analysis of the present disclosure can be applied to various phenomena and technical fields, and costs and time required for analysis can be reduced.

[0018] Further, according to the present disclosure, it is possible to accurately calculate a flow field to be analyzed using a second calculation lattice model while relatively quickly calculating an interface between a first fluid and a second fluid to be analyzed using a first calculation lattice model.

[0019] Furthermore, it is possible to stably calculate flow data by continuously calculating physical values, such as density or viscosity, from the interface between the first fluid and the second fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

In the detailed description that follows, embodiments are described as illustrations only since various changes and modifications will become apparent to a person with ordinary skill in the art from the following detailed description. The use of the same reference numbers in different figures indicates similar or identical items.

[0020] **FIG. 1** is a configuration diagram of a fluid analysis simulation device according to an embodiment of the present disclosure.

[0021] **FIG. 2** illustrates an example of a first calculation lattice model to be applied to a first governing equation and a second calculation lattice model to be applied to a second governing equation according to an embodiment of the present disclosure.

[0022] **FIG. 3** illustrates an example of initial conditions for a first fluid and a second fluid determined according to an embodiment of the present disclosure.

[0023] **FIG. 4** is a flowchart of a fluid analysis simulation method according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0024] Hereafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings so that the present disclosure may be readily implemented by a person with ordinary skill in the art. However, it is to be noted that the present disclosure is not limited to the embodiments but may be embodied in various other ways. In drawings, parts irrelevant to the description are omitted for the simplicity of explanation, and like reference numerals denote like parts through the whole document.

[0025] Throughout this document, the term “connected to” may be used to designate a connection or coupling of one element to another element and includes both an element being “directly connected” another element and an element being “electronically connected” to another

element via another element. Further, it is to be understood that the terms “comprises,” “includes,” “comprising,” and/or “including” means that one or more other components, steps, operations, and/or elements are not excluded from the described and recited systems, devices, apparatuses, and methods unless context dictates otherwise; and is not intended to preclude the possibility that one or more other components, steps, operations, parts, or combinations thereof may exist or may be added.

[0026] Throughout this document, the term “unit” may refer to a unit implemented by hardware, software, and/or a combination thereof. As examples only, one unit may be implemented by two or more pieces of hardware or two or more units may be implemented by one piece of hardware. However, the “unit” is not limited to the software or the hardware and may be stored in an addressable storage medium or may be configured to implement one or more processors. Accordingly, the “unit” may include, for example, software, object-oriented software, classes, tasks, processes, functions, attributes, procedures, sub-routines, segments of program codes, drivers, firmware, micro codes, circuits, data, database, data structures, tables, arrays, variables and the like. The components and functions provided by the “units” can be combined with each other or can be divided up into additional components. Further, the components and the “units” may be configured to implement one or more CPUs in a device or a secure multimedia card.

[0027] Throughout this document, a part of an operation or function described as being carried out by a terminal or device may be implemented or executed by a server connected to the terminal or device. Likewise, a part of an operation or function described as being implemented or executed by a server may be so implemented or executed by a terminal or device connected to the server.

[0028] Hereinafter, embodiments of the present disclosure will be explained in detail with reference to the accompanying drawings.

[0029] **FIG. 1** is a configuration diagram of a fluid analysis simulation device according to an embodiment of the present disclosure. Referring to **FIG. 1**, a fluid analysis simulation device 100 may include an input unit 110, a lattice generator 120, a data calculator 130, and a simulator 140.

[0030] The fluid analysis simulation device 100 according to the present embodiment may include a server, a desktop computer, a notebook computer, a kiosk, a smartphone, and a tablet PC. However, the fluid analysis simulation device 100 is not limited thereto. That is, the fluid analysis simulation device 100 may include all devices equipped with a processor capable of performing an LBM-based fluid analysis simulation method to be described later.

[0031] The fluid analysis simulation device 100 according to the present embodiment may perform a two-dimensional or three-dimensional flow analysis of a fluid. For example, the fluid analysis simulation device 100 models a two-dimensional or three-dimensional simulation region and a plurality of particles located in the simulation region, and analyzes the flow of the plurality of particles in the simulation region.

[0032] The fluid analysis simulation device 100 according to the present embodiment may perform a simulation for analyzing a fluid based on a Lattice Boltzmann Method (LBM). The LBM is one of the particle-type fluid analysis techniques which may be used in Computational Fluid Dynamics (CFD). In order to simulate a motion of a fluid, which is an analysis target, the LBM may express the fluid as particles on a lattice. The fluid analysis simulation device 100 may calculate a physical value of each particle while tracking each particle by the LBM, and perform a fluid analysis simulation based on the calculation result.

[0033] The input unit 110 may receive data about the analysis target for the fluid analysis simulation. For example, the input unit 110 may receive the data about the analysis target from an external device such as a user device.

[0034] The input unit 110 may also receive the data about the analysis target through communication with an external server. The data about the analysis target may include flow

information of the fluid, which is the analysis target, and information about analysis conditions. For example, the data about the analysis target may include at least one of an initial density, viscosity, and initial velocity of the fluid, which is the analysis target.

[0035] In the present embodiment, a multiphase or multicomponent fluid may be an analysis target. That is, in the present embodiment, the data about the analysis target may include a first fluid and a second fluid. The first fluid and the second fluid are fluids that have different phases or contain different components, and may be immiscible or may be in a non-mixed state.

[0036] The lattice generator 120 may generate a calculation lattice system and/or an output lattice system based on the received data. The lattice generator 120 may generate a lattice system for the entirety or a part of a space, which is an analysis target. The lattice generator 120 may determine a lattice spacing of the lattice system based on data such as a position and a velocity of the analysis target. The lattice generator 120 may generate a lattice system in which a lattice spacing varies depending on the region.

[0037] The lattice generator 120 may generate a calculation lattice system for calculating fluid component data and flow data. Specifically, the calculation lattice system generated by the lattice generator 120 may include a first calculation lattice model and a second calculation lattice model. The first calculation lattice model may be configured to calculate fluid component data of an interface between the first fluid and the second fluid, and the second calculation lattice model may be configured to calculate flow data of flow fields of the first fluid and the second fluid, respectively. The first calculation lattice model and the second calculation lattice model may be different lattice models.

[0038] **FIG. 2** illustrates an example of a first calculation lattice model to be applied to a first governing equation and a second calculation lattice model to be applied to a second governing equation according to an embodiment of the present disclosure.

[0039] Referring to **FIG. 2A**, in an embodiment of the present disclosure, the first calculation lattice model configured to calculate fluid component data based on the first governing equation may have 7 vectors in three dimensions (D3Q7). Also, referring to **FIG. 2B**, the second calculation lattice model configured to calculate flow data based on the second governing equation may have a greater number of vectors than the first calculation lattice model, and may have, for example, 19 vectors in three dimensions (D3Q19).

[0040] In the present embodiment, the data calculator 130 may calculate flow data of the analysis target based on the calculation lattice system. The data calculator 130 may use a Multi-Relaxation Time (MRT) model to calculate flow data.

[0041] The data calculator 130 may calculate fluid component data and flow data of a plurality of particles based on the calculation lattice system. The data calculator 130 may calculate fluid component data and flow data of a plurality of particles based on the calculation lattice system using the first calculation lattice model and the second calculation lattice model.

[0042] The data calculator 130 may use an LBM algorithm to calculate flow data generated by a movement of each particle or a collision between each particle and a neighboring particle on the lattice system.

[0043] The data calculator 130 may calculate a distribution function value of particles at each lattice point using the LBM algorithm and thus may obtain physical property information at each lattice point. The physical property information at each lattice point may include, for example, at least one of mass, velocity, viscosity, and acceleration of the particle. Further, the data calculator 130 may calculate fluid component data and flow data of each particle in a next time step based on a distribution function value of each particle.

[0044] In the present embodiment, fluid component data of the interface between the first fluid and the second fluid may be calculated based on the first governing equation. The first governing equation may be a Cahn-Hilliard equation, and may be represented by Equation 1 to Equation 3 below

through discretization of time and space with an LBGK model. The first calculation lattice model D3Q7 may be used for the interface between the first fluid and the second fluid.

[0045] [Equation 1]

$$f_i(x + c_i\Delta t, t + \Delta t) - f_i(x,t) = -\frac{1}{\tau_f}\left[f_i(x,t) - f_i^{eq}(x,t)\right] + \Delta t F_i(x,t)$$

[0046] [Equation 2]

$$f_i^{eq}(x,t) = \begin{cases} \phi + (\omega_i - 1)\eta\mu, & i = 0 \\ \omega_i\eta\mu + 3\omega_i(c_i \cdot \phi u), & i \neq 0 \end{cases}$$

[0047] [Equation 3]

$$F_i(x,t) = \left(1 - \frac{1}{2\tau_f}\right)3\omega_i(c_i \cdot \partial_t(\phi u))$$

[0048] Herein, c_i is the discrete velocity, τ is the shear stress, ϕ is the order parameter representing each fluid, w_i is the weighting, η is the mobility parameter, μ is the chemical potential, and u is the fluid velocity.

[0049] Also, a macroscopic value of a distribution function f may be defined by Equation 4 below, and a density ρ and a mobility M of the fluid may be represented by Equation 5 and Equation 6 below.

[0050] [Equation 4]

$$\sum_i f_i = \phi$$

[0051] [Equation 5]

$$\rho = \phi(\rho_1 - \rho_2) + \rho_2$$

[0052] [Equation 6]

$$M = \frac{\eta(\tau_f - 0.5)}{3}\Delta t$$

[0053] **FIG. 3** illustrates an example of initial conditions for a first fluid and a second fluid determined according to an embodiment of the present disclosure.

[0054] In the present embodiment, the data calculator 130 may calculate fluid component data and flow data in order for at least one physical value to be continuously changed at the interface between the first fluid and the second fluid.

[0055] Specifically, order parameters representing components of a first fluid Fluid 1 and a second fluid Fluid 2 are drastically changed at the interface between the fluids Fluid 1 and Fluid 2 when initial conditions are given. In the present embodiment, the phase-field approach as one of diffuse-interface methods is used to allow the density and viscosity to be continuously changed at the interface. Also, order parameters at the interface may be continuously expressed as the initial conditions by using a continuous function, *e.g.*, a hyperbolic tangent function.

[0056] Meanwhile, flow data of flow fields of the first fluid and the second fluid, respectively, may be calculated based on the second governing equation. The second governing equation may be a Navier-Stokes equation, and may be represented by Equation 7 to Equation 9 below through discretization of time and space with the second calculation lattice model D3Q19.

[0057] [Equation 7]

$$g_i(x + c_i\Delta t, t + \Delta t) - g_i(x,t) = -\frac{1}{\tau_g}\left[g_i(x,t) - g_i^{eq}(x,t)\right] + \Delta t G_i(x,t)$$

[0058] [Equation 8]

$$g_i^{eq}(x,t) = \begin{cases} 3p(\omega_i - 1) + \rho s_i(u), & i = 0 \\ 3p\omega_i + \rho s_i(u), & i \neq 0 \end{cases}$$

[0059] [Equation 9]

$$s_i(u) = \omega_i[3c_i \cdot u + 4.5(c_i \cdot u)^2 - 1.5u \cdot u]$$

[0060] Herein, p is the fluid pressure, and G_i in Equation 7 may be defined by Equation 10 and Equation 11 below.

[0061] [Equation 10]

$$G_i(x,t) = \left(1 - \frac{1}{2\tau_g}\right)3(c_i - u) \cdot \widetilde{G_l}$$

[0062] [Equation 11]

$$\widetilde{G_l} = \left[\frac{s_i(u)\nabla\rho}{3} + F_T(s_i(u) + \omega_i)\right]$$

[0063] Herein, F_T is the sum of F_s, F_a and G. Also, the surface tension force may be defined by $F_s = \mu\nabla\phi$, and the interfacial force may be defined by $F_a = 0.5(\rho_1 - \rho_2)M\nabla^2\mu u$. Further, a pressure p

and a velocity u, macroscopic values of a distribution function g, may be defined by Equation 12 and Equation 13 below.

[0064] [Equation 12]

$$u = \frac{\sum_i c_i g_i + 0.5\Delta t(F_s + G)}{\rho}$$

[0065] [Equation 13]

$$p = \frac{1}{3(1-\omega_o)}\left[\sum_{i\neq 0} g_i + \frac{\Delta t}{2} u \cdot \nabla\rho + \rho s_0(u)\right]$$

[0066] Meanwhile, in the present embodiment, a dynamic viscosity ί may be represented by Equation 14 below through a Chapman-Enskog analysis.

[0067] [Equation 14]

$$\nu = \frac{(\tau_g - 0.5)}{3}\Delta t$$

[0068] According to an embodiment of the present disclosure, the first calculation lattice model may be used to calculate fluid component data for tracking an interface of a multiphase or multicomponent fluid, and the second calculation lattice model may be used to calculate flow data of a flow field. The first calculation lattice model (for example, D3Q7) may sufficiently express the interface with a smaller calculation amount, and the second calculation lattice model (for example, D3Q19) may secure the accuracy in flow analysis. Therefore, the fluid analysis simulation device according to an embodiment of the present disclosure can perform an efficient flow analysis while reducing resources and time required for analysis.

[0069] Specifically, the second calculation lattice model that performs a calculation based on the second governing equation can stably and accurately analyze an immiscible multicomponent fluid as the directionality of the surface tension force F_s and the interfacial force F_a increases. Also, physical values including the density or viscosity at the interface between the first fluid and the second fluid are continuously calculated, and, thus, an analysis of flow data can be stably performed.

[0070] The data calculator 130 can calculate the flow of each particle by calculating flow data of each particle in each time step and thus can perform a fluid analysis simulation. The data calculator 130 may transfer the calculated fluid component data and flow data from the calculation lattice system to a lattice point of the output lattice system.

[0071] The simulator 140 may perform the fluid analysis simulation based on the output lattice system. The simulator 140 may perform a simulation for the plurality of particles by outputting the calculated flow data to the output lattice system.

[0072] **FIG. 4** is a flowchart of a fluid analysis simulation method according to an embodiment of the present disclosure. The fluid analysis simulation method performed by the device 100 illustrated in **FIG. 1** includes the processes time-sequentially performed by the device 100 illustrated in **FIG. 4.** Therefore, the above descriptions of the processes may also be applied to the fluid analysis simulation method performed by the device 100 according to the embodiment illustrated in **FIG. 1** even though they are omitted hereinafter.

[0073] In a process S410, the device 100 may receive data about an analysis target including a first fluid and a second fluid.

[0074] In a process S420, the device 100 may generate a calculation lattice system for calculating fluid component data and flow data based on the received data.

[0075] In a process S430, the device 100 may generate an output lattice system for outputting an analysis result.

[0076] In a process S440, the device 100 may generate calculate fluid component data and flow data of the analysis target based on the calculation lattice system. Fluid component data of an interface between the first fluid and the second fluid may be calculated based on a first governing equation, and flow data of flow fields of the first fluid and the second fluid, respectively, may be calculated based on a second governing equation.

[0077] In a process S450, the device 100 may perform a fluid analysis simulation based on the output lattice system.

[0078] In the descriptions above, the processes S410 to S450 may be divided into additional processes or combined into fewer processes depending on an exemplary embodiment. In addition, some of the processes may be omitted and the sequence of the processes may be changed if necessary.

[0079] The fluid analysis simulation method performed by the fluid analysis simulation device described above with reference to **FIG. 1** to **FIG. 4** can be implemented as a computer program stored in a medium to be executed by a computer or a storage medium including instructions executable by a computer. Also, the fluid analysis simulation method performed by the fluid analysis simulation device described above with reference to FIG. 1 to FIG. 4 can be implemented as a computer program stored in a medium to be executed by a computer.

[0080] A computer-readable medium can be any usable medium which can be accessed by the computer and includes all volatile/non-volatile and removable/non-removable media. Further, the computer-readable medium may include computer storage. The computer storage medium includes all volatile/non-volatile and removable/non-removable media embodied by a certain method or technology for storing information such as computer-readable instruction code, a data structure, a program module or other data.

[0081] The above description of the present disclosure is provided for the purpose of illustration, and it would be understood by those skilled in the art that various changes and modifications may be made without changing technical conception and essential features of the present disclosure. Thus, it is clear that the above-described embodiments are illustrative in all aspects and do not limit the present disclosure. For example, each component described to be of a single type can be implemented in a distributed manner. Likewise, components described to be distributed can be implemented in a combined manner.

[0082] The scope of the present disclosure is defined by the following claims rather than by the detailed description of the embodiment. It shall be understood that all modifications and embodiments conceived from the meaning and scope of the claims and their equivalents are included in the scope of the present disclosure.

EXPLANATION OF REFERENCE NUMERALS

100: Fluid analysis simulation device

110: Input unit

120: Lattice generator

130: Data calculator

140: Simulator

WE CLAIM

1. A fluid analysis simulation device based on a lattice Boltzmann method (LBM), comprising:

an input unit configured to receive data about an analysis target including a first fluid and a second fluid;

a lattice generator configured to generate a calculation lattice system to calculate fluid component data and flow data and an output lattice system to output an analysis result based on the received data;

a data calculator configured to calculate fluid component data and flow data of the analysis target based on the calculation lattice system; and

a simulator configured to perform the fluid analysis simulation based on the output lattice system,

wherein the data calculator calculates fluid component data of an interface between the first fluid and the second fluid based on a first governing equation, and flow data of flow fields of the first fluid and the second fluid based on a second governing equation.

2. The fluid analysis simulation device of Claim 1,

wherein the calculation lattice system includes:

a first calculation lattice model configured to calculate fluid component data based on the first governing equation; and

a second calculation lattice model configured to calculate flow data based on the second governing equation and having a greater number of vectors than the first calculation lattice model.

3. The fluid analysis simulation device of Claim 2,

wherein the first calculation lattice model has 7 vectors in three dimensions (D3Q7), and

the second calculation lattice model has 19 vectors in three dimensions (D3Q19).

4. The fluid analysis simulation device of Claim 1,

wherein the first governing equation is represented by Equations below through discretization of time and space.

$$f_i(x + c_i\Delta t, t + \Delta t) - f_i(x,t) = -\frac{1}{\tau_f}\left[f_i(x,t) - f_i^{eq}(x,t)\right] + \Delta t F_i(x,t)$$

$$f_i^{eq}(x,t) = \begin{cases} \phi + (\omega_i - 1)\eta\mu, & i = 0 \\ \omega_i\eta\mu + 3\omega_i(c_i \cdot \phi u), & i \neq 0 \end{cases}$$

$$F_i(x,t) = \left(1 - \frac{1}{2\tau_f}\right) 3\omega_i(c_i \cdot \partial_t(\phi u))$$

5. The fluid analysis simulation device of Claim 1,

wherein the data calculator calculates fluid component data and flow data in order for at least one physical value to be continuously changed at the interface between the first fluid and the second fluid.

6. The fluid analysis simulation device of Claim 1,

wherein the second governing equation is represented by Equations below through discretization of time and space.

$$g_i(x + c_i\Delta t, t + \Delta t) - g_i(x,t) = -\frac{1}{\tau_g}\left[g_i(x,t) - g_i^{eq}(x,t)\right] + \Delta t G_i(x,t)$$

$$g_i^{eq}(x,t) = \begin{cases} 3p(\omega_i - 1) + \rho s_i(u), & i = 0 \\ 3p\omega_i + \rho s_i(u), & i \neq 0 \end{cases}$$

$$s_i(u) = \omega_i[3c_i \cdot u + 4.5(c_i \cdot u)^2 - 1.5u \cdot u]$$

7. A fluid analysis simulation method based on a lattice Boltzmann method (LBM), comprising:

receiving data about an analysis target including a first fluid and a second fluid;

generating a calculation lattice system to calculate fluid component data and flow data based on the received data;

generating an output lattice system to output an analysis result;

calculating fluid component data and flow data of the analysis target based on the calculation lattice system; and

performing the fluid analysis simulation based on the output lattice system,

wherein in calculating fluid component data and flow data includes calculating fluid component data of an interface between the first fluid and the second fluid based on a first governing equation, and calculating flow data of flow fields of the first fluid and the second fluid, respectively, based on a second governing equation.

8. A computer program that is stored in a computer-readable storage medium and includes a sequence of instructions to perform a lattice Boltzmann method (LBM)-based fluid analysis simulation,

wherein the computer program includes a sequence of instructions that, when executed by a computing device, causes the computing device to receive data about an analysis target including a first fluid and a second fluid,

to generate a calculation lattice system to calculate fluid component data and flow data based on the received data,

to generate an output lattice system to output an analysis result,

to calculate fluid component data and flow data of the analysis target based on the calculation lattice system, and

to perform the fluid analysis simulation based on the output lattice system, and

fluid component data of an interface between the first fluid and the second fluid are calculated based on a first governing equation, and flow data of flow fields of the first fluid and the second fluid, respectively, are calculated based on a second governing equation.