

論文 / 著書情報
Article / Book Information

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種別(和文)	論文要旨
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(博士課程)
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論文要旨

THESIS SUMMARY

系・コース： Department of Graduate major in	機械 機械	系 コース	申請学位 (専攻分野)： Academic Degree Requested	博士 Doctor of	(Engineering)
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要旨 (英文 800 語程度)

Thesis Summary (approx.800 English Words)

The forest resources are abundant in Japan. However, frequent typhoons and floods can easily uproot trees into river channels and turn them into driftwood pieces. Consequently, pieces of driftwood carried by river floodings can lead to secondary disasters, which pose a significant threat to human life and property. With the development of CFD methods and computer hardware such as GPU, large-scale 3-D problems of high complexity have been allowed to be simulated and analyzed on supercomputers. In order to better understand driftwood disasters and enhance research in this field, we have applied numerical simulation codes to contribute to the prediction and mitigation of driftwood-related disasters.

Chapter 1 “Introduction” illustrates the damage caused by driftwood and provides background information on driftwood trap devices, which are frequently used to mitigate the hazards from driftwood disasters. After that, a review of previous experimental and numerical research is presented. These approaches have some limitations and disadvantages. For example, it is difficult for experiments to observe the movement of driftwood underwater and to accurately calculate the porosity of driftwood accumulation areas. In addition, previous numerical simulations tended to use coarse grids, making it challenging to ensure the accuracy of driftwood movement calculations. Brief development histories of numerical methods used in this thesis, such as LBM, CPF, and AMR, are then introduced. Based on the above introduction, two primary objectives of this thesis are formulated: to contribute to the prediction of driftwood disasters (through simulations for a real disaster) and to their mitigation (through simulating driftwood trap devices) by using numerical simulations and high-resolution grids.

Chapter 2 “Numerical Method” provides an overview of the numerical methods employed in this research, along with their coupling techniques. In order to investigate flows with driftwood, we compute the fluid dynamics of water and the motion of driftwood by taking into account the interaction between the water and the driftwood. The cumulant lattice Boltzmann method (cLBM) enables stable and fully explicit calculations of fluid flows with high Reynolds numbers, the discrete element method (DEM) can precisely compute the translational and rotational motion of driftwood and the conservative phase field (CPF) method ensures superior gas-liquid interface capturing. The integration of the coupling techniques assures the feasibility of simulating complex multi-physics scenarios including water, air, riverbeds, buildings, driftwood, and trap devices.

Chapter 3 “Adaptive Mesh Refinement Method” introduces the details of the adaptive mesh refinement (AMR) method and its coupling with cLBM. The AMR method has the ability to assign high-resolution grids around interfaces where high precision is needed and assign low-resolution grids to other areas. This feature makes it possible to perform 3-D large-scale simulations using high-resolution grids. The octree-typed block-structured AMR method is adopted in this thesis due to the relatively simple arrangement rules. To couple with cLBM, the interpolation of velocity distribution functions is required in the AMR meshes near the resolution boundaries.

Chapter 4 “3-D Simulation of Real River Flooding with Driftwood” gives the results and explanations of simulations for a real river flooding disaster with driftwood that happened in Iwaizumi Town, Japan. First, the accuracy of the present method is validated by simulating the small-scale experiments and comparing the computational results, which are in good agreement with the experimental results in terms of the shape of the water surface, water heights, the trapping rate of the driftwood, the angle formed between the trapped driftwood and the water surface, wave impact, and collision force. As an application, two large-scale computations are conducted as case studies based on the actual river flooding disaster including 1,000 pieces of driftwood and a maximum resolution of 7.8125 [cm]. The simulation results show that the proposed model could generally replicate the inundation process and the driftwood accumulation positions like the real disaster.

Moreover, three driftwood accumulation processes are found: trapping in narrow channels, hitting building corners, and stagnation in front of buildings.

Chapter 5 “3-D Simulation for Driftwood Trapping” identifies the factors that affect the capture effectiveness and the dammed-up depth of a driftwood trap device installed on a real-scale impervious concrete dam. First, simulation results for two hydraulic model experiments show good agreement with the experimental results, thereby validating the feasibility of the proposed method in simulating the interactions between the driftwood, the trap device, and the water flow. For a real-scale dam with a driftwood trap device, we examine flows including 1,000 pieces of driftwood with different parameters. It is found that the number of trapped pieces of driftwood strongly depended on the driftwood length. Namely, more than 90% of driftwood is captured when the length is greater than 75% of the trap device gap. We show that the driftwood distribution under the water and the angle to the water surface is smaller for longer driftwood due to the combined effects of buoyancy and downward water flow. Additionally, it is discovered that the dammed-up depth in front of the trap device has a strong correlation with the porosity and the width of the trapped area. The degree of occlusion, which is calculated from porosity and width, can be used as an indicator for evaluating the dammed-up depth.

Chapter 6 “Conclusion” gives the conclusion, the originality, and future works of this doctoral research. Large-scale 3-D simulations of real river flooding with driftwood and the real-scale driftwood trap device installed on a concrete dam using GPU supercomputers demonstrate the capability of our numerical methods in simulating these scenarios with high accuracy. It is our deepest hope that this humble contribution to the prediction and mitigation of driftwood disasters will help reduce damage and better protect human lives.

備考：論文要旨は、和文 2000 字と英文 300 語を 1 部ずつ提出するか、もしくは英文 800 語を 1 部提出してください。

Note: Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1 copy of 800 Words (English).

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