VIRTUAL LABORATORY FOR SIMULATION OF FLUID DYNAMICS PROBLEMS WITH FREE BOUNDARIES BY SPH

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Abstract: *Virtual laboratory for simulation of fluid flows with free boundaries by SPH is presented in this paper. The laboratory is training, it has next objectives: study the SPH method, study of fluid flows and determination of the influence of physical parameters on fluid flow.*

Numerical experiment is a fairly complex method of the research, because it requires a good understanding of physical phenomena nature and numerical methods knowing. Most numerical methods require fine-tuning set of parameters, so the topical issue is to build simulators for numerical simulating technique studying and the acquirement of skills in numerical methods use.

In this paper the virtual laboratory is the environment that allows the student to learn the basics of the numerical method and reconstruct the sequence of steps for the numerical simulation, prepare the initial data for computing problem, perform calculations, and consider various options for displaying results of calculations. The virtual laboratory can be used as a part of the laboratory course in numerical simulation technique, SPH, as well as to fluid mechanics studying.

The personal pre and postprocessor GiD is used to prepare the initial data, and visualization of results in a virtual laboratory. SPHysics package is used for calculation.

Introduction

A virtual laboratory VLSPH for acquirement of the numerical simulation technique using smoothed particle hydrodynamics method (SPH) is present in this paper. Using of virtual laboratories can make the learning process more interesting; facilitate better understanding of the subject as well as practical skills acquirement. The employment of virtual laboratories is especially important when the work in the real laboratories is dangerous or expensive.

At present the numerical simulation is one of the methods for the study of the physical phenomena like fluid dynamics together with the experimental and analytical methods. The numerical simulation is a sufficient complex research method, because it requires both a good understanding of physical phenomena nature and numerical methods knowing. The modern numerical methods are quite complex and require fine-tuning a set of parameters. Therefore the topical issue is to build simulators for numerical simulating technique studying and the acquirement of skills in numerical methods use.

In this paper the virtual laboratory is an environment that allows students to study the theoretical foundations of SPH and to reconstruct the sequence of steps of the numerical experiment: preparing the initial data for a calculation (preprocessing), executing it (processing), and considering various ways of displaying computation results (postprocessing). Simpler variant of the laboratory use is considering and modification ready calculations of test problems that are included as a part to the laboratory for the determination of numerical method parameters influence to decision quality.

The virtual laboratory for a simulation of the fluid dynamics problems with free boundaries by SPH is a training laboratory, which has the next objectives:

- studying mesh free method SPH;
- studying of the fluid flows;
- the determination of physical parameters influence to fluid flow.

The virtual laboratory can be used as a part of the laboratory course in numerical simulation technique, SPH, as well as to fluid mechanics studying.

VLSPH architecture

The personal preprocessor and postprocessor GiD is used to prepare the initial data and visualization of the results in the virtual laboratory. The SPHysics package is used for the numerical calculation.

GiD was chosen as a tool for preprocessing and postprocessing because it is a universal adaptive tool, adjustable at both the subject area of the problem being solved and the using numerical method. Additional GiD advantage is that allows creating custom forms for the parameters input and presentation of educational materials. Besides it is one of the few packages that can work with mesh free numerical methods. The main contents of the laboratory is realized as a problem type VLSPH (Virtual Laboratory for SPH), enlarged by a set of projects realizing test and demonstration problems.

SPHysics package that is included to the laboratory as a solver based on one of the most popular mesh free methods SPH in FORTRAN. The SPHysics chosen as a solver, because in this package are realizing the majority of developments in SPH: represented a wide range of kernel functions, different time schemes, different types of viscosity and boundary conditions realization, as well as a wide range of variable parameters to a tuning the numerical method. Package supplemented by a set of test problems which have an analytical decision or decision calculated by other numerical methods: stretching liquid ellipse problem[i], liquid sloshing

problem[ii], the problem of the fluid flow between two fixed rigid boundaries[iii], as well as the problem of the destruction of a semi-circle hollow. This set allows students to make the verification of the numerical method. Also the lab includes a set of problems, which demonstrate capability of SPH on the simulation of flows with an essential free surface deformation: dam break in a box, dam break evolution over a wet bottom in a box, waves generated by a paddle in a beach, tsunami generated by a sliding Wedge[iv]. Also student can calculate some new problems.

Work with virtual laboratory

Work in the laboratory involves the consistent accomplishment of the three stages of the numerical experiment: preparation of initial data (preprocessing), computing (processing), visualization and analysis of the results (postprocessing). Each stage is performed in several steps. This sequence is shown detailed in Figure 1.

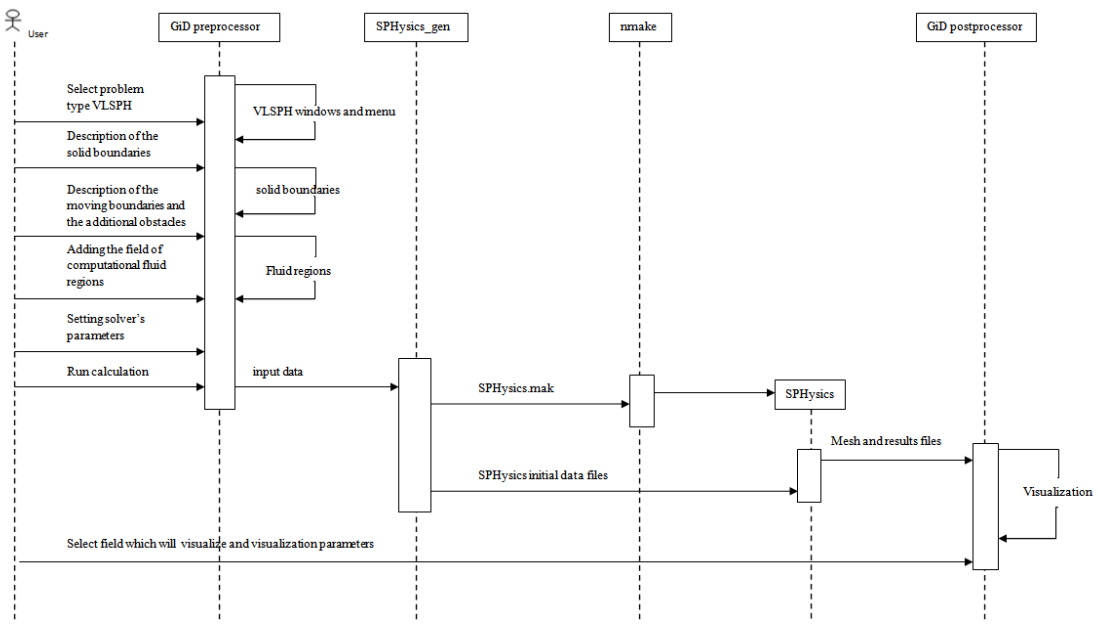

Figure 1. Sequence diagram of VLSPH.

As a result each of the three phases can be divided into several components. The final sequence of steps is as follows:

1. reading reference manual;
2. description of the solid boundaries;
3. description of the moving boundaries and the additional obstacles;
4. adding the field of computational fluid regions;
5. setting solver's parameters;
6. calculation;
7. results visualization.

Primarily a student should learn the method of SPH and the basic virtual laboratory using in a reference manual. It contains information about the SPH method, describes the sequence of work, as well as on a number of how-to examples for the acquirement of skills in laboratory using. If the students have sufficient knowledge in this subject, they can skip this step and go directly to the consideration of test problems or to implementation their own.

The stage of preprocessing is the steps 2-5. Consider them in detail.

1. The boundaries are described as a non-closed polygonal line in a box with vertical and /or tilted boundaries. It's possible to use two kinds of geometric configurations of the boundaries, conventionally called "the box" and "the beach".
2. Description of additional obstacles and moving boundaries. If the condition of the simulated problem does not require such facilities they can skip this step and go to step filling liquid.
3. Adding of the regions filled by the liquid. In accordance with the requirements of SPHysics liquid should be added by rectangular regions (in the case of an inclined surface may be filled by the triangular region). In the case of more complex liquids fields, it should be divided into several simple regions.
4. Setting the parameters of calculations. The parameters window includes two tabs: basic method parameters and time parameters.

When the preparation of the data is completed they are transferred to the computing module SPHysics for numerical calculations.

After computing SPHysics sends to GiD the mesh and the results files that was prepared by its computational module. After loading data into the postprocessor, students can begin the final phase of their work with the virtual laboratory - visualization of results. To estimate calculation quality and analyze the fluid flow students should consider the velocity, pressure and density fields.

A broad functional for the visualization of various results of numerical calculations is implemented in GiD. Therefore, in the laboratory used the standard GiD features. To acquire skills of working with these functions students can use the GiD reference manuals.

Conclusion

VLSPH based on SPH and use GiD for preprocessing and postprocessing. The using of this virtual laboratory can make learning of fluid dynamics more engrossing.

References

[i] Ovsyannikov L.V. General equation and examples . The problem of unstable flow with free boundaries// Novosibirsk: Nauka, 1967 (in Russian) .

[ii] K.E. Afanasiev, R.S. Makarchuk, A.Yu. Popov Comparative Analysis of the SPH and ISPH Methods // Notes on numerical fluid mechanics and multidisciplinary. Volume 101. Computational Science and Performance Computing III. Springer, 2007. Page 206-223.

[iii] Sedov L.I. Flow mechanics// Moscow: Nauka, 1973 (in Russian).

[iv] User Guide for SPHysics code http://wiki.manchester.ac.uk/sphysics/index.php/SPHYSICS_Home_Page.