Smoothed-particle hydrodynamics for microfluidics

MATH0471 – Spring 2024

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v.1 (06/02/2024)

This project consists in studying, implementing and validating a numerical scheme for the solution of Navier-Stokes equations using the "smoothed-particle hydrodynamics" (SPH) computational method in the context of microfluidic applications. SPH originated in the late 1970's for astrophysical problems, and has been used since then in numerous application areas. The method is a mesh-free, particle-based Lagrangian method, where the coordinates move with the fluid (particles).

We ask you to study, implement and test the SPH method presented in the following reference: Louis Goffin, "Development of a didactic SPH model", Travail de fin d'études réalisé en vue de l'obtention du grade de Master Ingénieur Civil des Constructions, Université de Liège, année académique 2012-2013. Then you will extend the method to handle surface tension, adhesion and viscosity effects to handle realistic microfluidic applications.

The project is organized with 4 deadlines, and with students divided into 3 groups. For each intermediate deadline, one max. 4 page progress report (mandatory, but not graded) is due, associated with a Git tag and describing the development status. For the final deadline, a report of max. 60 pages is due, that presents the method and the numerical results, the computer implementation and a detailed analysis of physical experiments on non-trivial configurations.

1. Serial implementation of the kernel and of the particle search using the linked list method described in Section 3.2.4 of L. Goffin's thesis; validation and performance testing of the search algorithm; parameter handling using JSON.

   Intermediate deadline: **February 28th**.

2. OpenMP implementation of 3D SPH for the Navier-Stokes formulation described in L. Goffin's master thesis using an Explicit Euler and a two-step Runge Kutta scheme; validation and performance testing of the code on the falling water cube test-case from Section 5.1.1 of L. Goffin's thesis.

   Intermediate deadline: **March 27th**

3. Literature review for handling surface tension, adhesion and viscosity effects; first tests of microfluidics applications.

   Intermediate deadline: **April 24rd**

4. Selected choice of advancement developments: GPU acceleration, advanced microfluidics applications, ...

   Final deadline: **May 17th**

An oral presentation of the main project results will be organized during the June exam session; individual theoretical and practical questions will be asked to each member of the student groups.