Research proposal

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For positions for research in the fields of simulation and visualization of massive particle quantities, The University of Siegen

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Outline

My programming experience

I worked as programmer more than 11 years in different fields:

- Microprocessor programming
- Web programming
- Mobile programming (application and games)
- System programming
- Scripting for different purposes

My scientific experience

I studied several subjects useful for the current position:

- Algorithms and algorithmic languages, data structures (bachelor and master)
- Computer architecture, computer practicum etc (bachelor)
- Fluids dynamics (master)
- Classical simulation with particles (master)
- Continuum and discrete-continuum models (master)

Two main approach in fluids visualization

It is well known two main methods of fluids simulation handling:

Mesh-based calculation (Computational fluid dynamics)

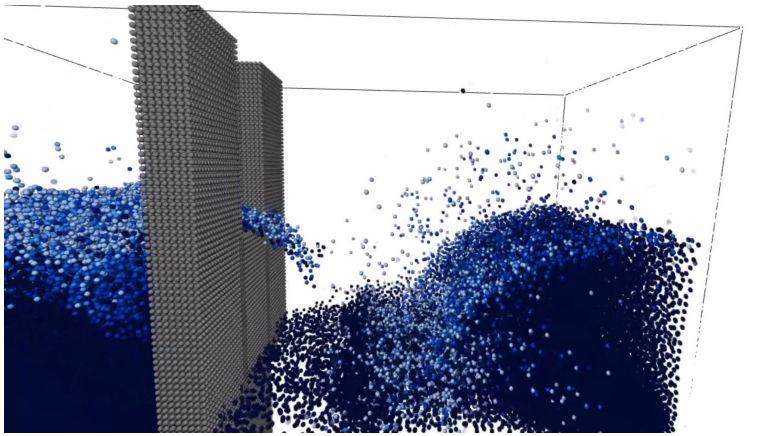
+ very good for elastic materials
+ precise for detailed simulation
- not well suited for parallel computation
- strict dependency on mesh quality

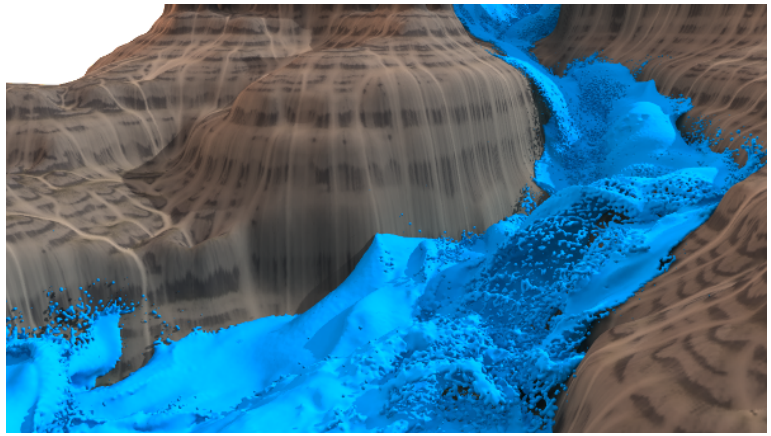
Mesh-free calculation (Smoothed-particle hydrodynamics)

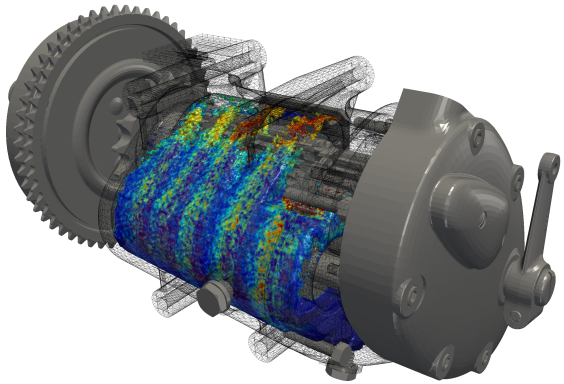
+ very good for fluids (liquids and gases)
+ good suited to complex phase boundary dynamics
+ not related to system of linear equations solution
- not enough precise for micro scale studies

Possible application of SPH

Dam water flow simulation, fluid flow inside engine, visualization for films







My research proposal

In recent study [2] it was proposed a new formulation for modeling solidification and melting. Authors offer is to use integral interpolation for heat conduction modeling for surface between phases. This method helps to avoid virtual particles and hence it is faster and yet more accurate. So, my proposition is to use such a method for simulation and visualization of more complex solid structures like polycrystals and martensite. It does not mean simulation of these solid structures' behavior but simulation of solidification, melting and vaporization of them.

Polycrystalline structure solidification and melting

It is well know fact that polycrystalline structure consists of gains. And main issue is dealing with these grains in order to show correct structure.

- We can use Monte-Carlo methods to achieve random location of polycrystall's new seeds on solid surface
- Add some extra term in classical equations for velocity and forces in order to keep distance between particles within the same lattice constant
- Rethink surface definition according to orientation of grains in order to draw up grain boundaries
- Use existing results [3] for simulating melting of grains

Martensite crystalline structure

It is very interesting if it possible to use smoothed particle hydrodynamics simulation to obtain such complex structures as martensite and similar from the liquid state. I suppose it is possible but we need:

- Modify somehow behavior of smoothed particles near freezing surface of solid, because during forming of martensite particles move with high speed (order of 1000 meter per second) and in fact is diffusion free
- There is also problem with sampling (because of speed) and in this case we can adapt Courant-Friedrichs-Lewy [4] criterion for SPH.
- Rethink surface definition according to the martensite structure

Methods that can be used

- As was mentioned I am going to use integral interpolation for surfaces in order to simulate surface-liquid interaction.
- Besides this I am going to use some techniques described in Kai Pan dissertation [1]. Especially fluid-solid coupling used in this work.
- We will need a combination of greed-based and greed-free techniques because we are dealing with solid and liquid and in extended simulation we will deal with solid and gas.
- Sampling should be discussed because this approach will directly influence stability and precision of obtained results.
- Integration rule which is more convenient for this task will be chosen during some computational and visualization experiments. I am not ready to say exact methods that will be used.
- CUDA, OpenCL, Fluids v.3 etc

References I

1. Kai Pan, Simulating Fluid-Solid Interaction Using Smoothed Particle Hydrodynamics Method, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Feburary 2017
2. Amirsaman Farrokhpanah, Markus Bussmann, Javad Mostaghimi, New smoothed particle hydrodynamics (SPH) formulation for modeling heat conduction with solidification and melting, Numerical Heat Transfer, Part B: Fundamentals, 71(4), pp. 299-312, April 2017
3. Jussi Leinonen, Annakaisa von Lerber, Snowflake Melting Simulation Using Smoothed Particle Hydrodynamics, , Atmospheres, 6 February 2018
4. Desbrun M., Gascuel MP. (1996) Smoothed Particles: A new paradigm for animating highly deformable bodies. In: Boulic R., Hégron G. (eds) Computer Animation and Simulation '96. Eurographics. Springer, Vienna