Particle Based Fluids Animation

by

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Doctor of Philosophy in Software Engineering

2012

Faculty of Science and Technology

University of Macau

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CO-SUPERVISORS: Prof. Pheng-Ann Heng, Prof. Hanqiu Sun

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At University of Macau By Yuanzhang Chang

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Abstract

The Smoothed Particle Hydrodynamics (SPH) method has been widely used recently since its particle-based nature results in good characteristics for handling large topological deformation and small-scale features like bubbles, splashes and foams. In this thesis, the SPH method is exploited to animate various fluid behaviors.

The first contribution of this thesis is proposing a method for viscoelastic fluids simulation. In order to achieve viscoelastic flow behaviors, an additional elastic stress term is included in the traditional Navier-Stokes (NS) equation. Also, each SPH particle is endowed with two attributes, viscosity and elastic stress coefficient. By updating the particle values of the two attributes according to the temperature variation, melting and flowing phenomena such as lava flow and wax melting can thereby be reproduced.

We also propose a new method for high viscosity fluid simulation. A new elastic stress term, derived from a modified form of the Hooke's law, is included in the NS equation to animate the movements of the high viscosity fluids. To eliminate the particle deficiency problem near the boundary, a corresponding ghost particle is created when the distance of a particle to the boundary is smaller than a certain threshold.

We subsequently make an investigation on how the SPH method can be employed to conduct granular flow. The aforementioned elastic stress term for high viscosity fluid can also be used to handle the friction of granular materials. Additionally, viscosity force is added in the momentum equation to simulate dynamic friction which smoothens the velocity field and further maintains the simulation stability.

Finally, we focus on the acceleration of fluid simulation. We extend the idea of adaptive sampling by defining two physical criteria on Reynolds number and vorticity, which are exploited to evaluate particle importance. When a particle's corresponding values are smaller than the predefined Reynolds number and vorticity thresholds, it is labeled as unimportant. Then certain unnecessary calculations can be eliminated. Our experiments demonstrate that the method can be applied to improve the simulation performance without sacrificing visual quality.

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List of Abbreviations

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
ACM	Association for Computing Machinery
CFL	Courant-Friedrichs-Lewy
CG	Computer Graphics
CGF	Computer Graphics Forum
CPU	Central Processing Unit
CUDA	Compute Unified Device Architecture
DEM	Discrete Element Method
FEM	Finite Element Method
FLIP	Fluid-Implicit-Particle Method
FVM	Finite Volume Method
GPU	Graphics Processing Unit
GPGPU	General-Purpose Computation on the GPU
LBM	Lattice Boltzmann Method
MC	Marching Cubes
MD	Molecular Dynamics
MLS	Moving Least Squares
MPS	Moving Particle Semi-Implicit Method
NNPS	Nearest Neighboring Particle Searching
NS	Navier-Stokes
PIC	Particle-In-Cell Method
SIGGRAPH	Special Interest Group on Graphics and Interactive Techniques
SPH	Smoothed Particle Hydrodynamics
TOG	ACM Transactions On Graphics
VOF	Volume-Of-Fluid