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Animating Sand as a Surface Flow

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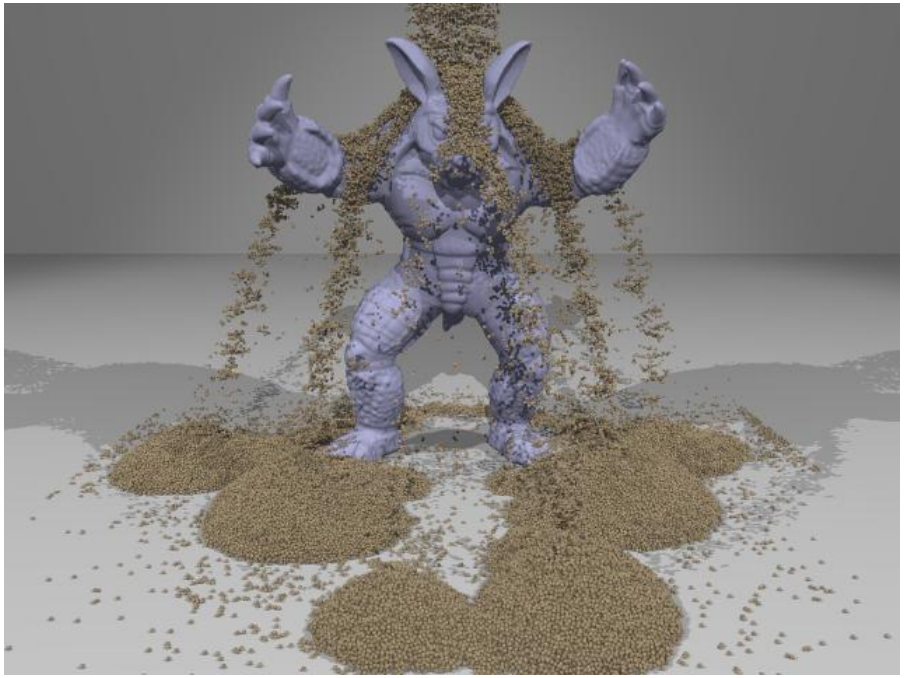
Motivation

- Animating scenes containing both dynamic and static granular phenomena.
- Handling the two motion states efficiently and combining them in one model.



Related Work

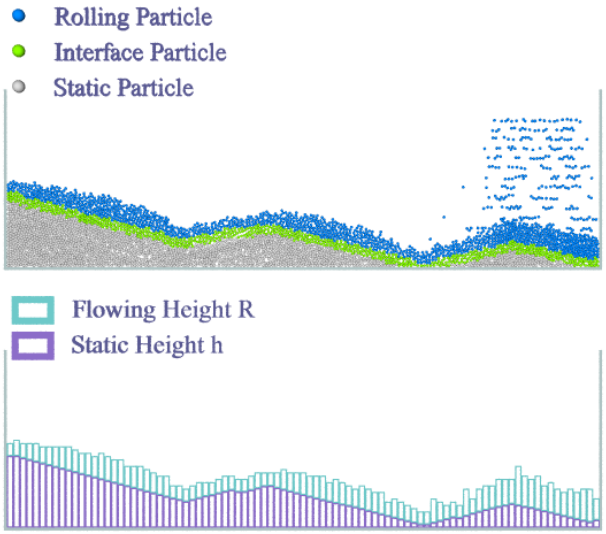
- Animating Sand as
  - Discrete Particles (DEM)
    - Bell et. al. Particle-based simulation of granular materials. SCA'05.
  - Height Fields
    - Sumner et. al. Animating Sand, Mud, and Snow. PG'99.
  - Continuums
    - Zhu and Bridson. Animating Sand as a Fluid. SIGGRAPH'05.

Related Work

- DEM
  - Treating each grain as a particle
  - Producing rich visual details
  - Computational efficiency is a problem
- Height Field
  - Using 2D height field columns to represent volume
  - Extremely Fast
  - Cannot simulate 3D effects

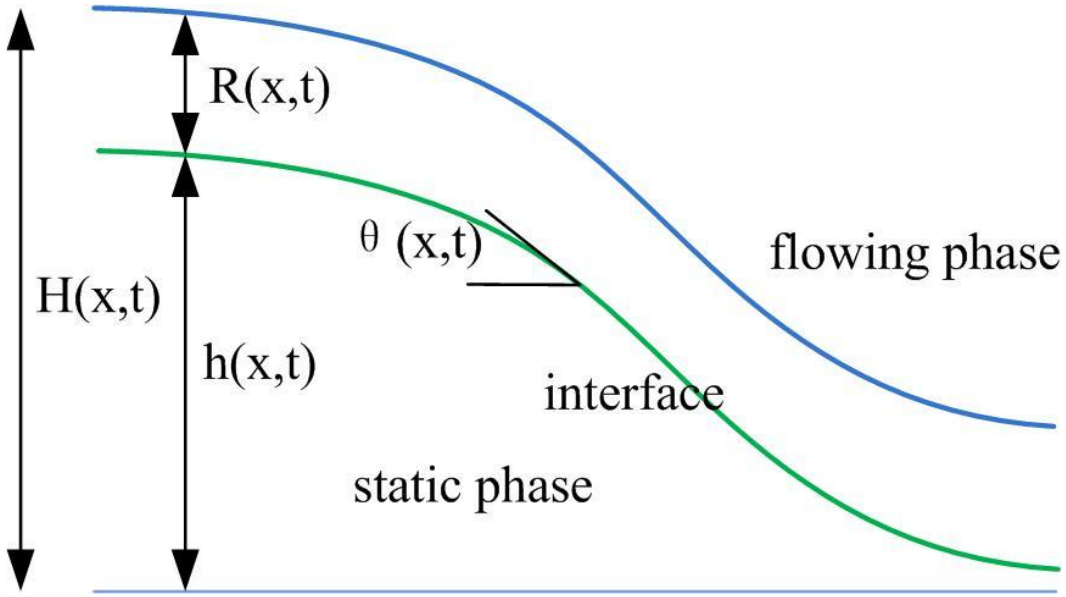
Method Overview

- A method coupling 2D/3D techniques.
  - A height field for the interior bulk.
  - Discrete particles for the flowing surface.
  - A physically based way for coupling.



The unique nature of sand

- Flow only exists in a surface layer.
- The large interior part is immobile.



How to determine the two layers?

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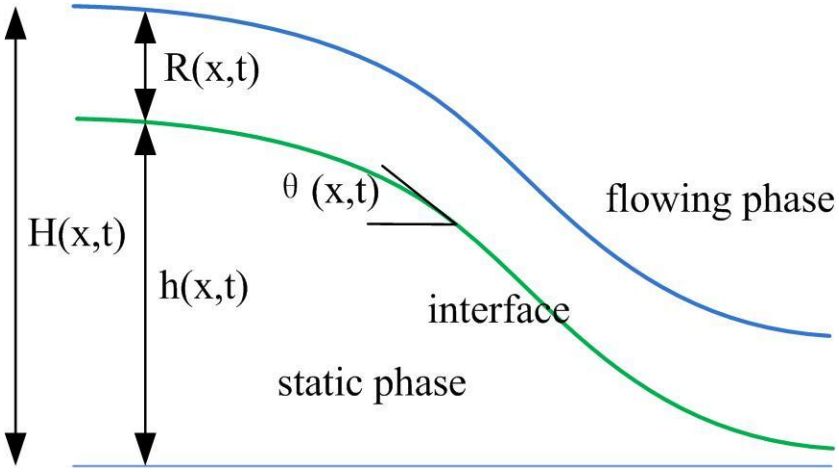
The BCRE Model

- Bouchaud, Cates, Ravi Prakash, Edwards.
- A Surface flow model based on height field.
- Subdividing the sand pile into a flowing layer and a static layer.
- A sharp interface evolving with time based on the BCRE equations.

Mathematics Model

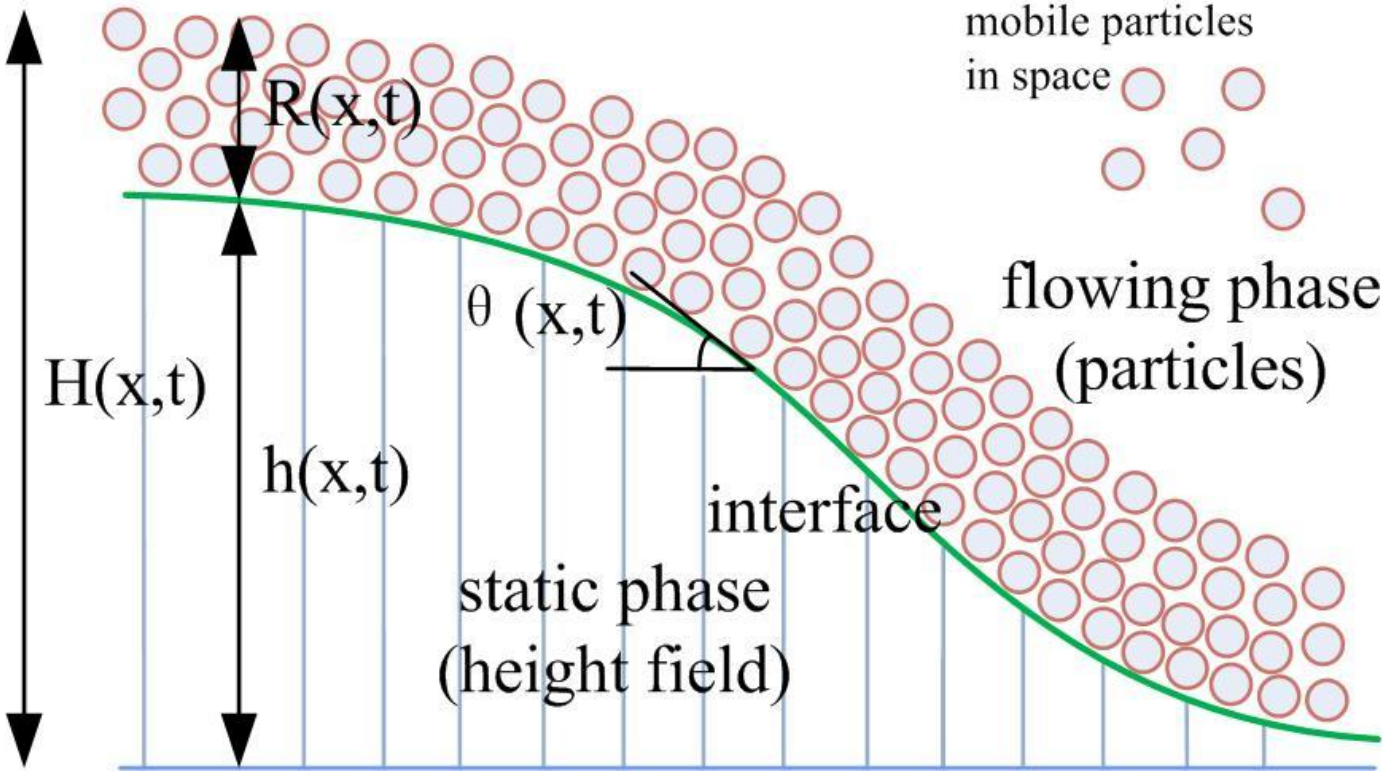
- BCRE Equations:
  - Height of Static Layer: $$\frac{\partial h}{\partial t} = -\varepsilon(x,t)$$
  - Height of Flowing Layer: $$\frac{\partial R}{\partial t} = v_d \frac{\partial R}{\partial x} + \varepsilon(x,t)$$
  - Exchange Term: $$\varepsilon(x,t) = \gamma R(\theta - \theta_0)$$



$$\theta > \theta_0 : Erosion$$

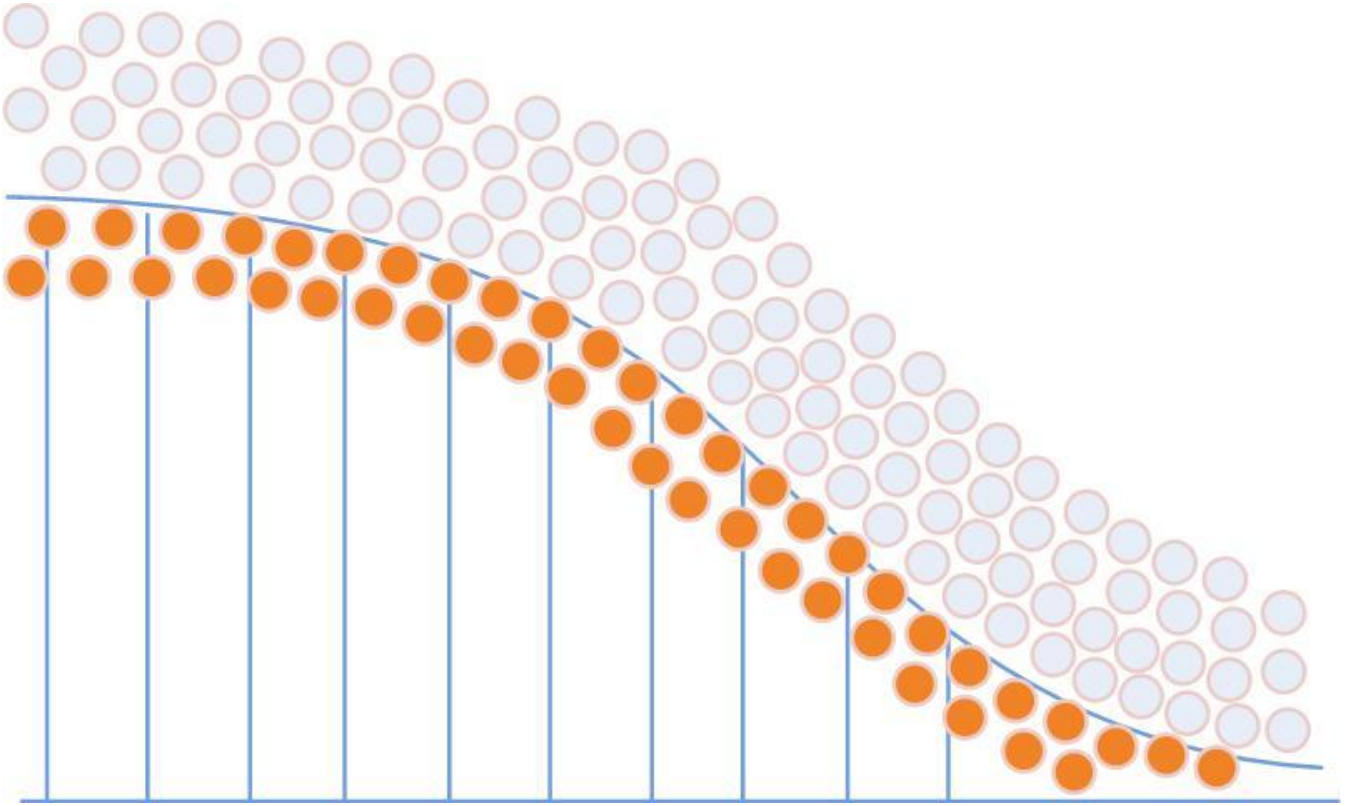
$$\theta < \theta_0 : Deposition$$

Coupling BCRE and DEM



Matter Transfer

- Particle-based erosion and deposition.



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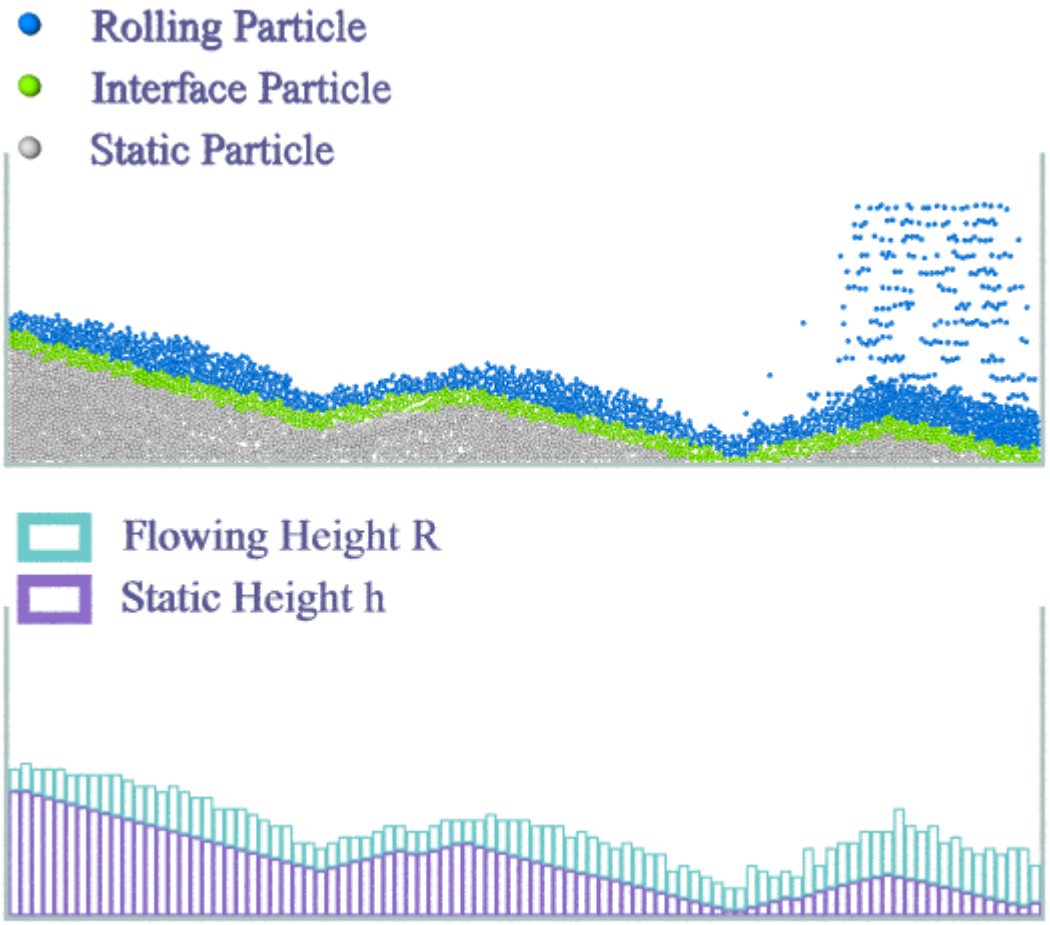
Hybrid Algorithm

- Ray casting from interface to surface layer.
- Two-layer height field evolution based on BCRE.
- Matter transfer through dynamic particle interface.
- Surface detail simulation with DEM solver.

Results—2D Demo

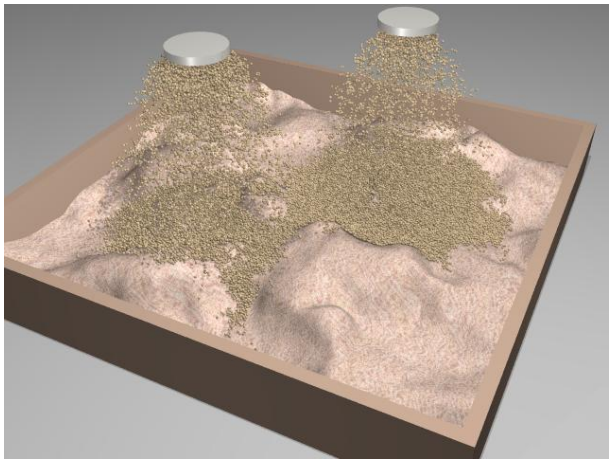


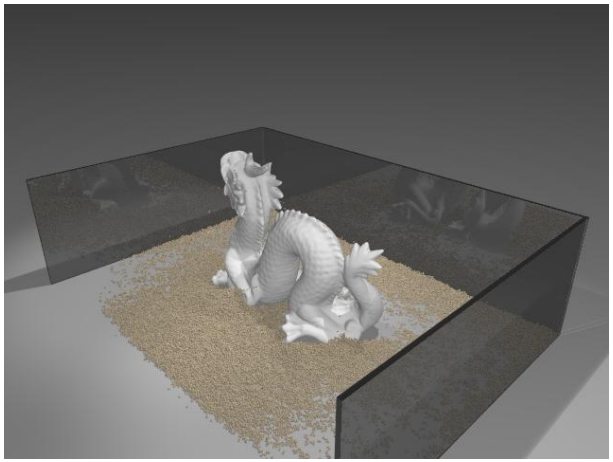
Results—Comparing with DEM

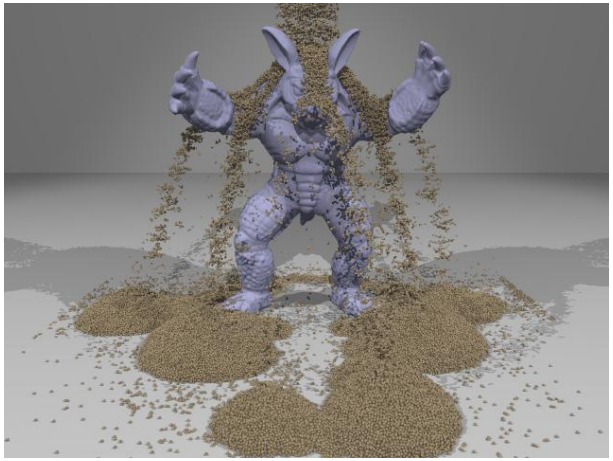
Standard DEM (68s/frame)

Our Approach (9s/frame)

Results—Other Demos







Results

- Particle number can be reduced to 10%-30%.
- Time step: 0.3-1.0ms.

Table 1: Particle numbers and timing data

Scenes	Total	Surface	Time(s/frame)
Floor	107,687	28,410	8.62
Terrain	199,039	48,423	18.27
Bowl	318,053	24,710	11.01
Dragon	192,975	40,043	30.05
Armadillo	207,020	58,540	21.54

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Conclusions

- A Hybrid 2D/3D Model.
  - Coupling BCRE and DEM.
  - Discrete particles: visible and rolling part
  - Height field: invisible and static part
  - Matter transfer: a dynamic particle interface
- Advantages.
  - Modeling the sand pile formation efficiently.
  - Saving both memory and computational time.
- Disadvantages.
  - Depends on the characteristics of the sand flow.

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Outlook

- Interaction with other materials, such as rigid objects, fluids.
- Appling this idea to fluid animation, coupling the height field model (SWE) and particle model (SPH)?
- Animating other natural phenomena, such as avalanche.

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The End.

Thank you for your attention!