Physical Animation of Wetting Terrain and Erosion

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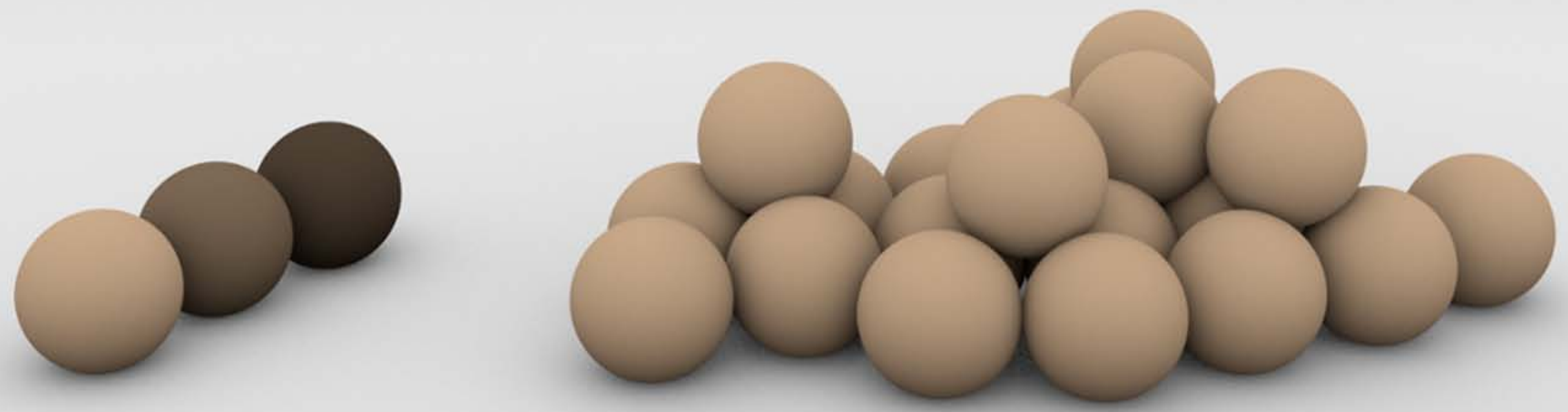


Supervised by: Doc. RNDr. Roman Ďurikovič, PhD.

Problem

- terrain erosion
- mass movement

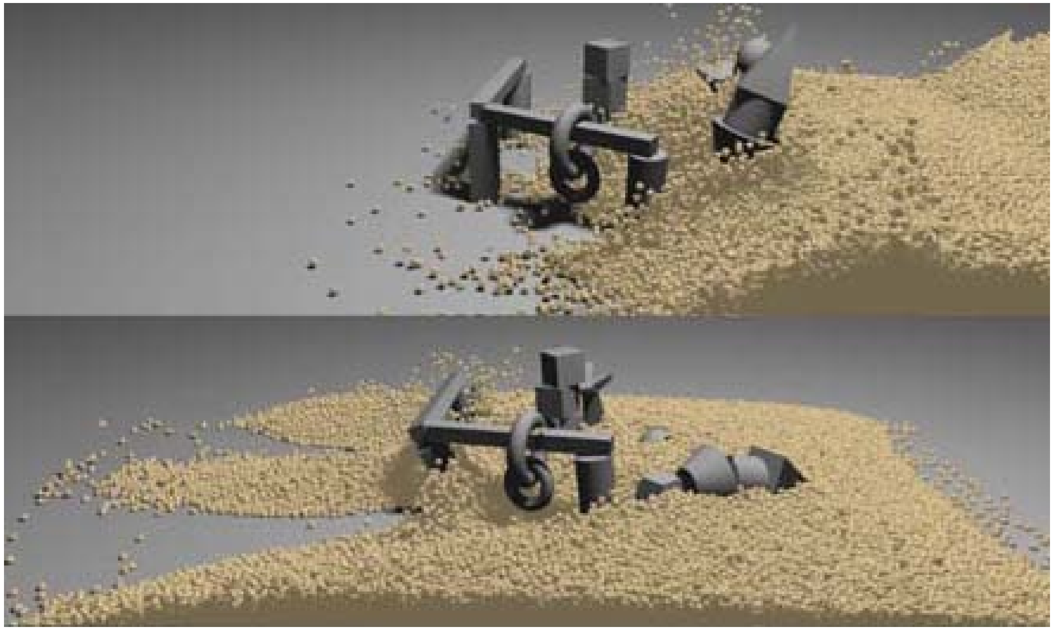
Motivation

- wetness in terrain erosion
- underlying structures
- soil system
- granular material
- particle – based simulation

Related Work

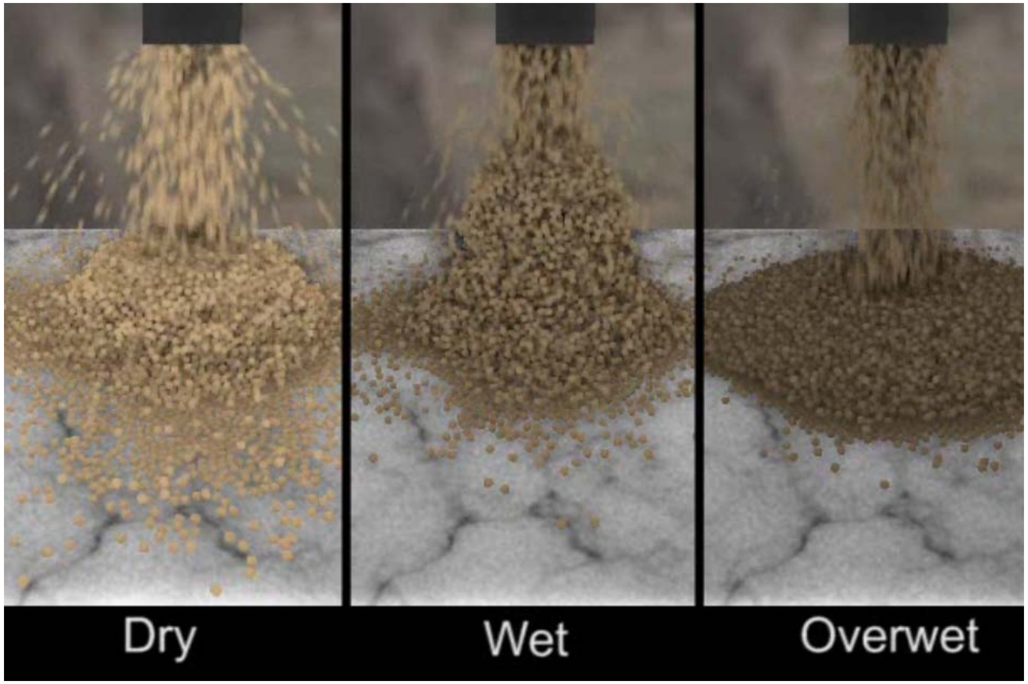
- Cundall [CUN79] - Discrete Element Method
- 2D simulation, falling rigid rocks
- not cohesive
- rigid particles

Related Work II



- DEM revisited by Bell et al. [BYM05]
- different friction forces
- real world friction – angle of repose cca 20° [LEE92]

Related Work III

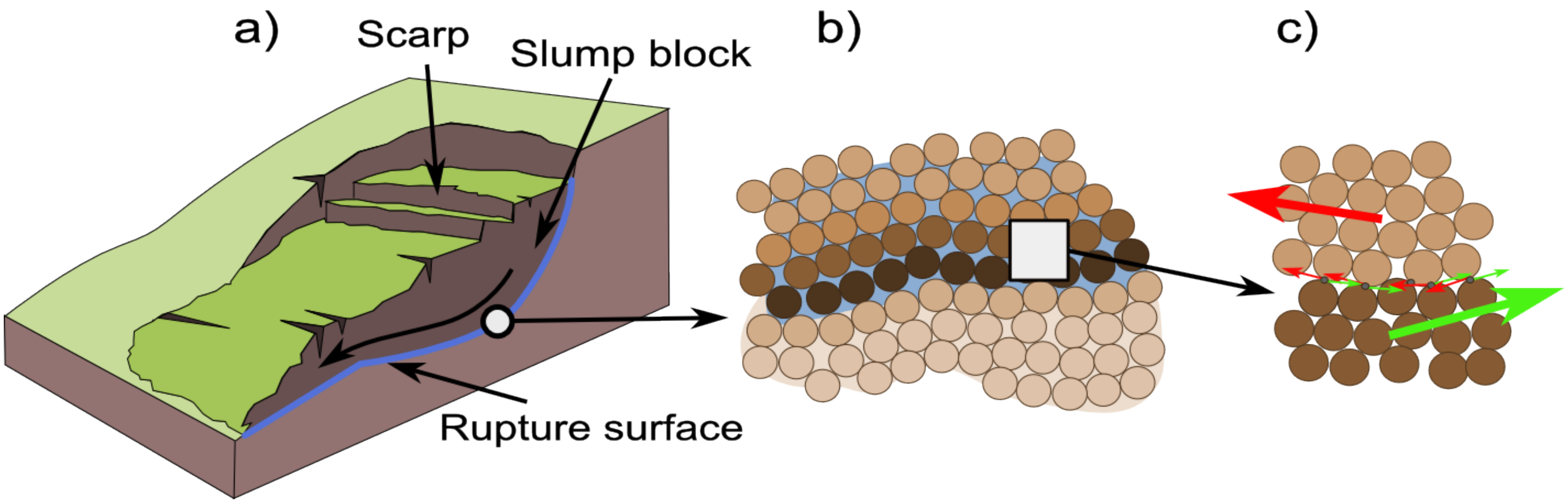


- wetness system. [RUN08]
- particles are dry, wet and overwet
- cohesion, liquid bridge

Our Approach

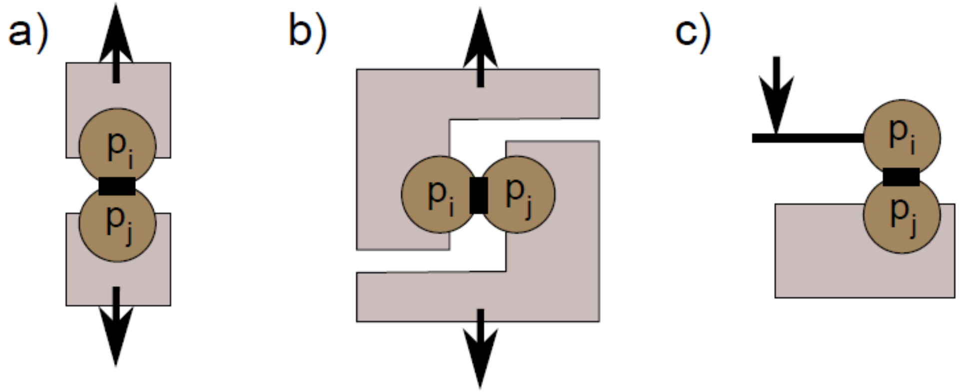
- soil system with DEM
- water system with SPH [CHLA10]
- wetting system
- layers, non homogeneous material
- wetness, cohesion, stability

Assumption



- wetness between layers ⟶ mass movement

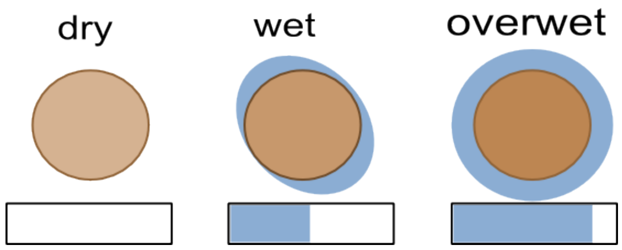
Bonds

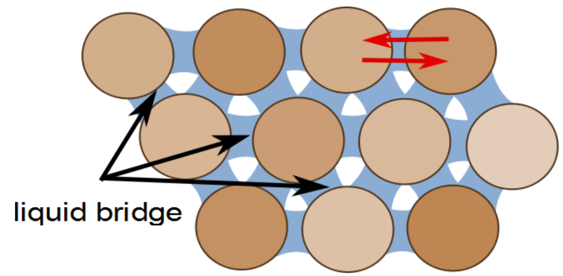


$$\overrightarrow{B_n} = (R_n/\xi) * \overrightarrow{N}$$

- bonding effect in natural sands [JIANG06]
- limitation in DEM contact forces
- normal, tangential, angular
- higher strength, material stability
- most in dry soil

Cohesion



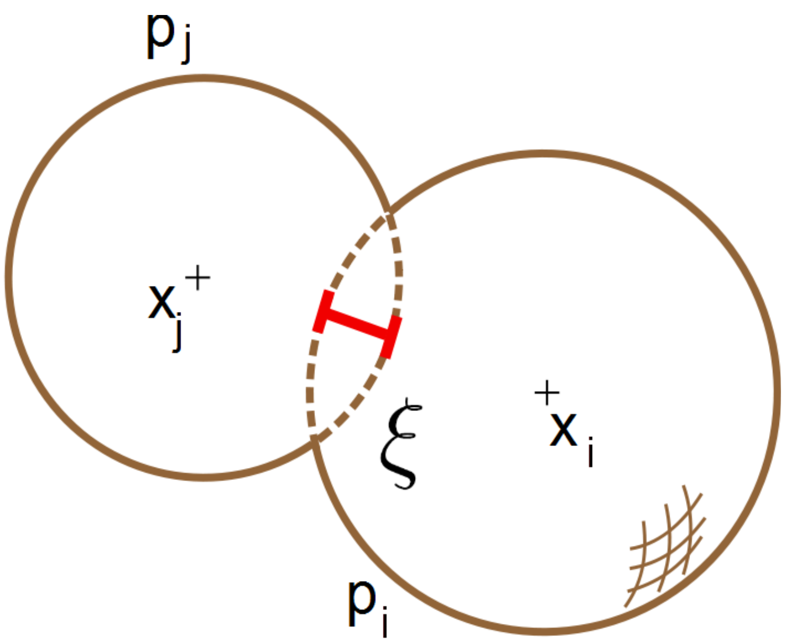


$$\overrightarrow{F_i^{attract}} = max\left\{0,\ w_f - \frac{w_i + w_j}{2}\right\}(v_j - v_i)$$

$$w_i^{t+\Delta t} = w_i^t + k_p \frac{\Delta w_i^t}{N_i}\Delta t$$

- wet particles
- liquid bridge
- water particles $\longrightarrow$ wetness contribution
- water aggregation speed
- most in wet material

Contact Model Pipeline



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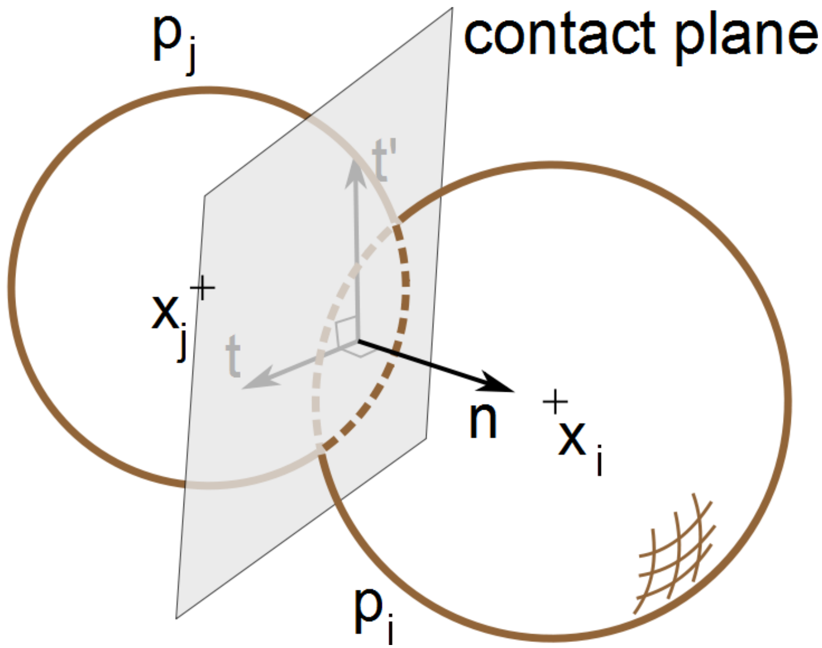

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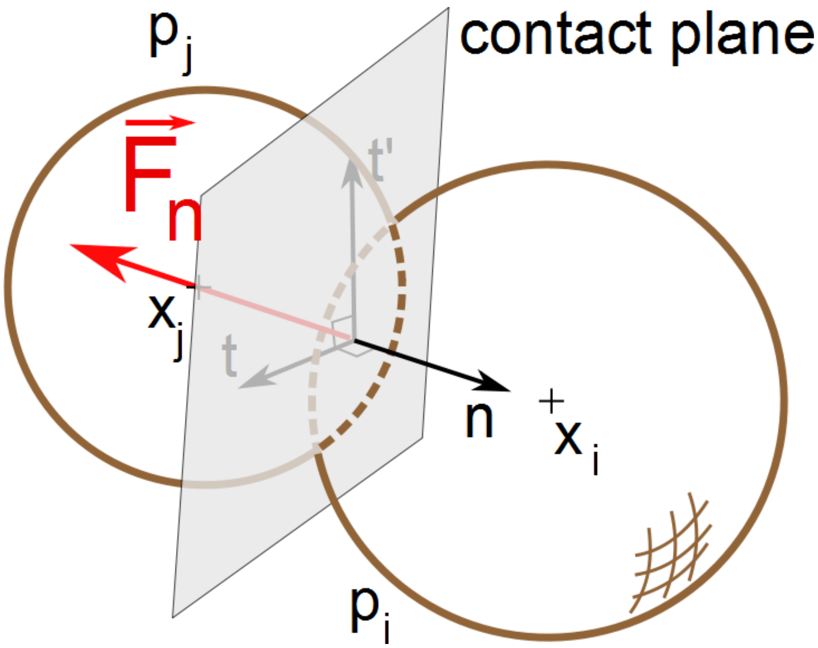
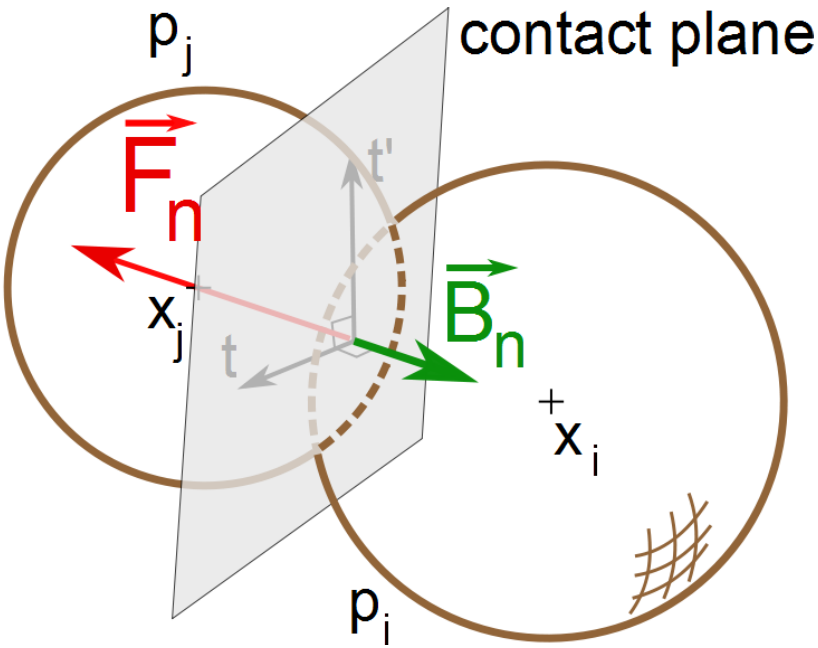


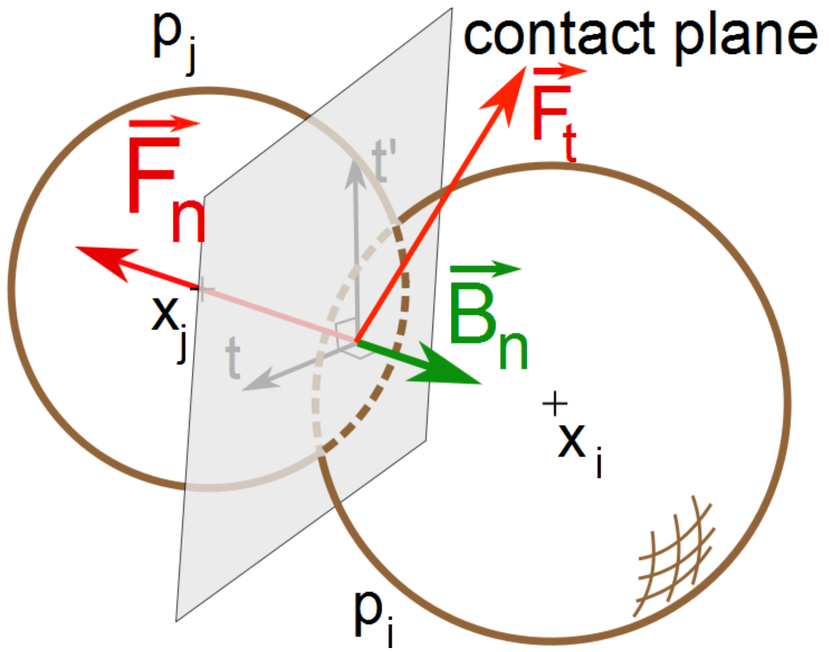
$$\vec{F_n} = k_s \xi \frac{\vec{N}}{||\vec{N}||} + k_d \vec{N}$$

Contact Model Pipeline



$$\vec{F}_n = k_s \xi \frac{\vec{N}}{||\vec{N}||} + k_d \vec{N} - (R_n/\xi)\vec{N}$$

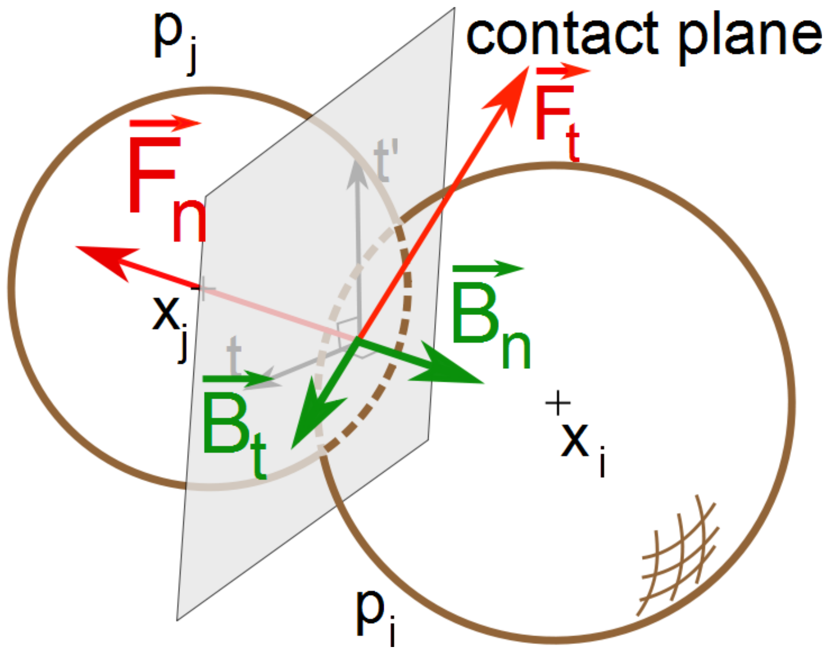
Contact Model Pipeline



$$\vec{F_n} = k_s \xi \frac{\vec{N}}{||\vec{N}||} + k_d \vec{N} - (R_n/\xi)\vec{N}$$

$$\vec{F_t} = -min(\mu f_n, k_t ||\vec{V_t}||) \frac{\vec{V_t}}{||\vec{V_t}||}$$

Contact Model Pipeline



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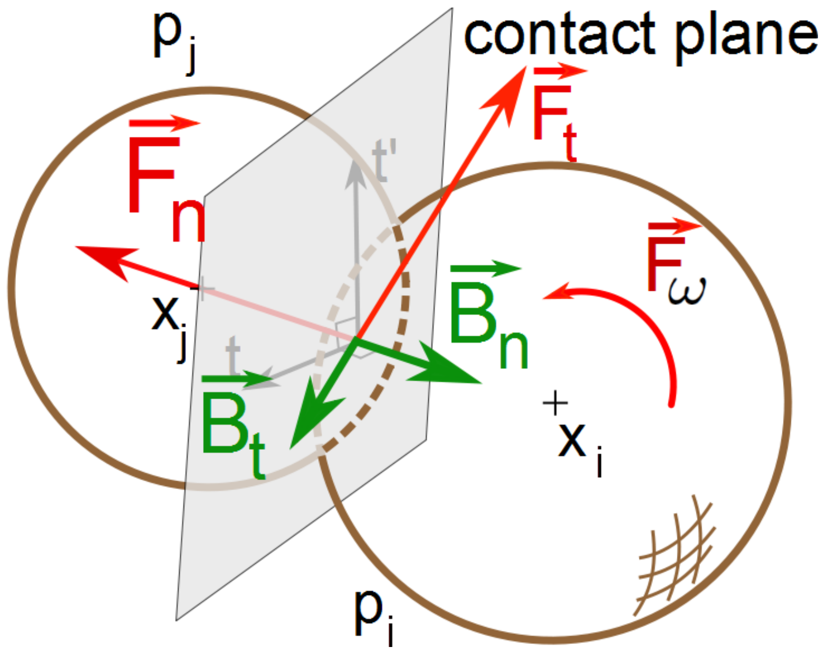

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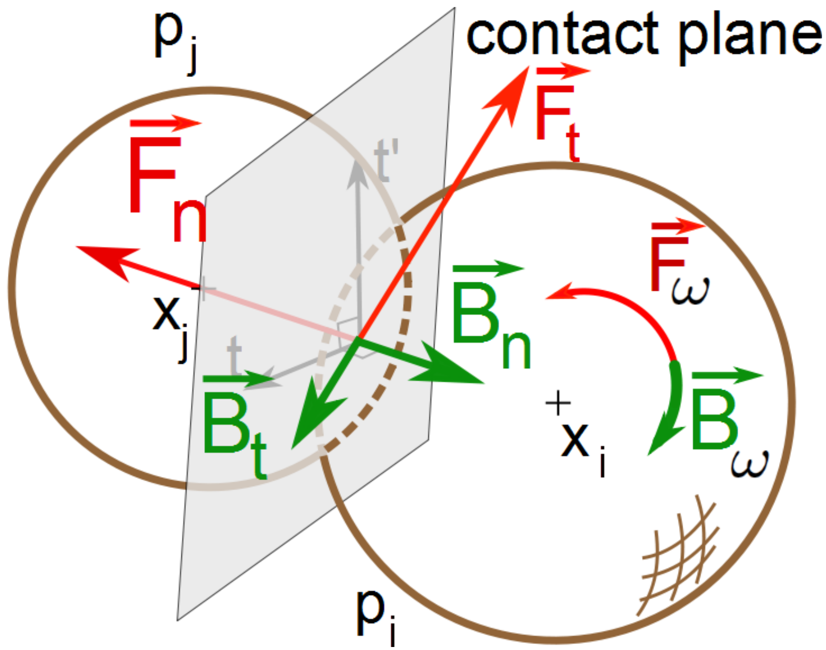
$$\overrightarrow{F_\omega} = (\overrightarrow{x} - \overrightarrow{p_i}) \times \overrightarrow{F_n} + (\overrightarrow{x} - \overrightarrow{p_i}) \times \overrightarrow{F_t}$$

Contact Model Pipeline



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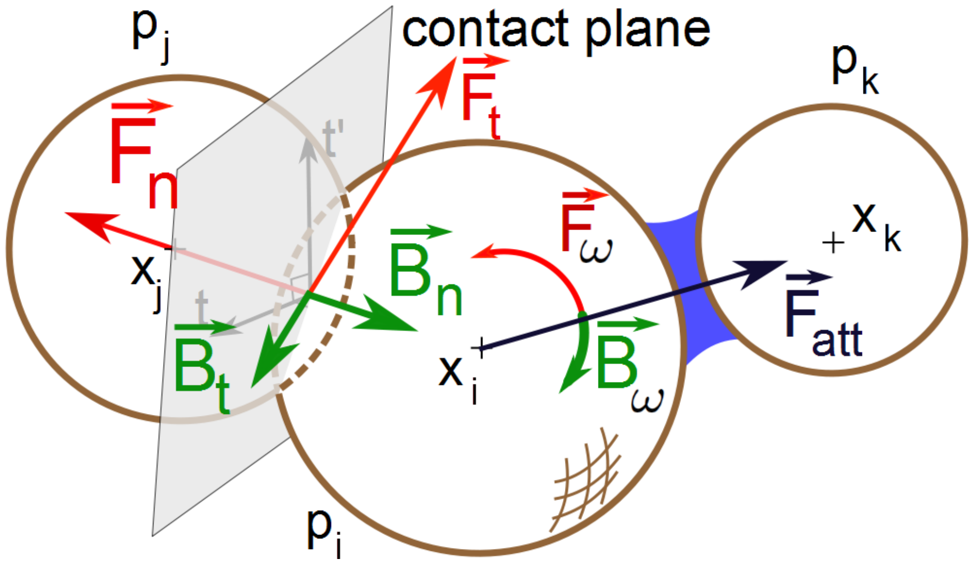
Contact Model Pipeline



$$\overrightarrow{F_n} = k_s \xi \frac{\overrightarrow{N}}{||\overrightarrow{N}||} + k_d(1 + w_i + w_j)\overrightarrow{N} - (R_n/\xi)\overrightarrow{N}$$

$$\overrightarrow{F_t} = -min(\mu(1 + w_i + w_j) f_n,\ k_t(1 + w_i + w_j)||\overrightarrow{V_t}||)\frac{\overrightarrow{V_t}}{||\overrightarrow{V_t}||} + (R_t/\xi)\frac{\overrightarrow{V_t}}{||\overrightarrow{V_t}||}$$

$$\overrightarrow{F_\omega} = (\overrightarrow{x} - \overrightarrow{p_i}) \times \overrightarrow{F_n} + (\overrightarrow{x} - \overrightarrow{p_i}) \times \overrightarrow{F_t} - (R_\omega/\xi)\overrightarrow{V_\omega}$$

$$\overrightarrow{F_i^{attract}} = max\left\{0,\ w_f - \frac{w_i - w_j}{2}\right\}(v_j - v_i)$$

Technical Parameters

Simulation

- C++, QT
- input – Blender + 3D scan line
- CPU, OpenMP

Visualization

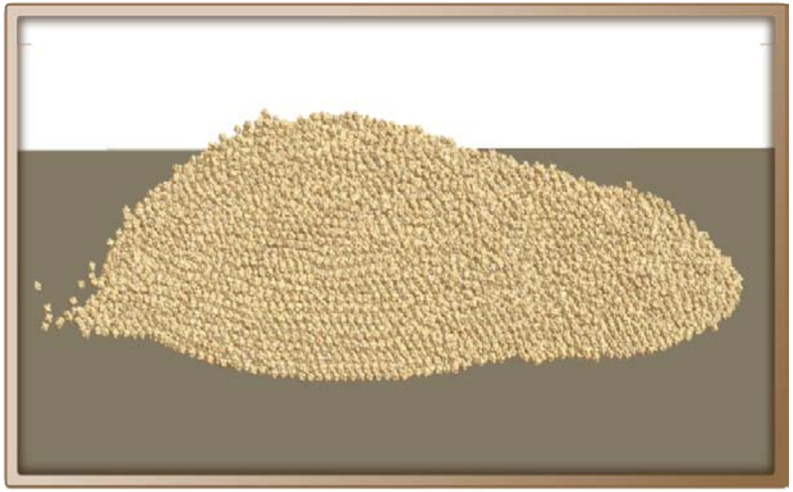
- internal – OpenGL

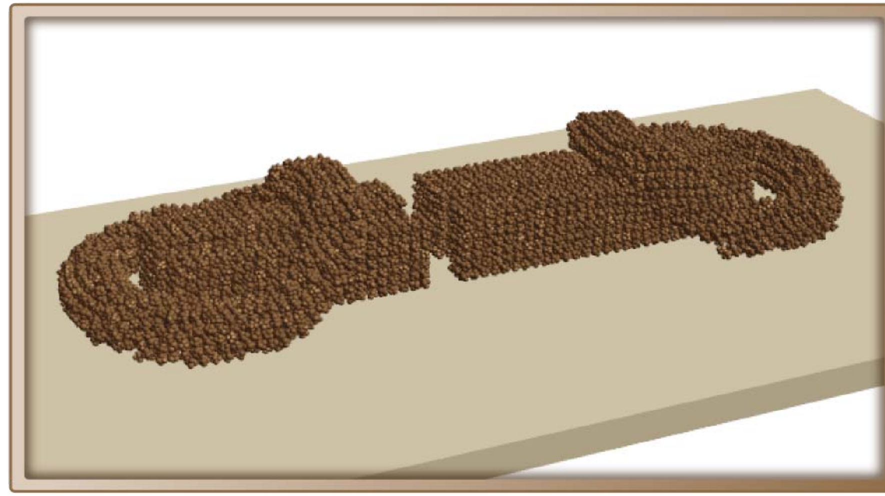
Results

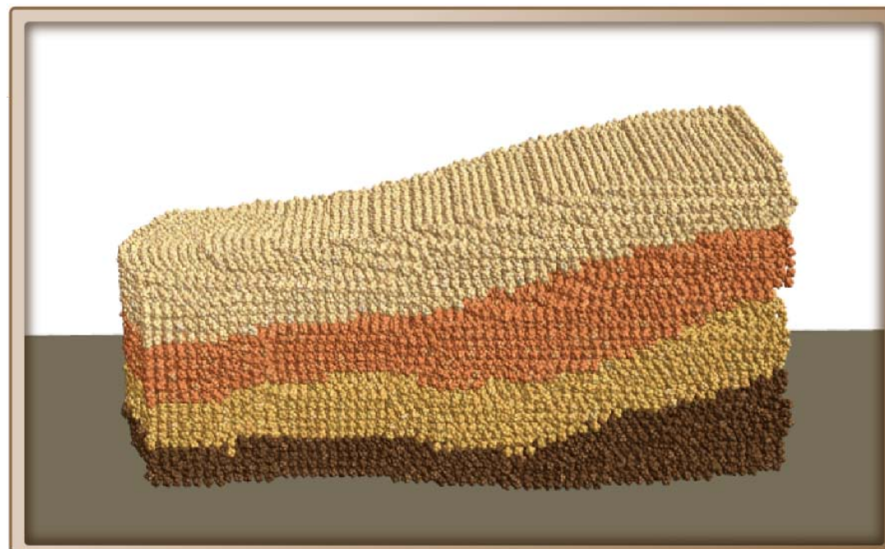
scene	particles	1 core	openMP	time step
sand	130k	0.2 fps	6 fps	0.001
wetness	20k	7 fps	13 fps	0.0005
input	50k	4 fps	5 fps	0.0002
hill	30k	2 fps	3 fps	0.0001
layers	60k	1.2 fps	3.4 fps	0.0002

- 5 categories / 5 different types of scenes
- material with different properties
- stability
- wetness system
- slide, movement

Results







Conclusion and Future Work

Conclusion

- wetness in terrain erosion, soil like material

Future Work

- natural input
- real time simulation
- drying of wet material
- underlying caves and water

Acknowledgement

- Michal Chládek and Juraj Onderik – SPH

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Thank you for your attention