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Falling over or Sliding down?

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Problem

- In animations , frictional contact models have been widely used in many areas like rigid body collision and soft body deformation. Given a simple geometric method to construct the difference between friction and non-friction at the in-contact moment.

Previous work

- Staggered sequence of projections
  ---Velocity-level
  ---Friction with contact impulses
  [Kaufman, Sueda, James and Pai 2008]
- Convex optimization based algorithm
  ---Nonpenetration
  [Drumwright and Shell 2009]
- Interpenetration volume constraints
  ---Tangent space basis
  ---Volume-based contact constraints
  [Allard et al. 2010]
- Nonsmooth Newton algorithm
  ---Simulation thin elastic rods
  [Descoubes, Cadoux, Daviet and Acary 2011]

Challenges

- The traditional methods put Coulomb friction condition into contact function and use different kinds of iterative LCP solvers to get a global or local result. The complexity of the algorithm becomes the main bottleneck for the frictional contact model.

Our method

- We use the FEM to calculate the deformation of soft bodies with different materials and give a simple geometry method to represent the friction.

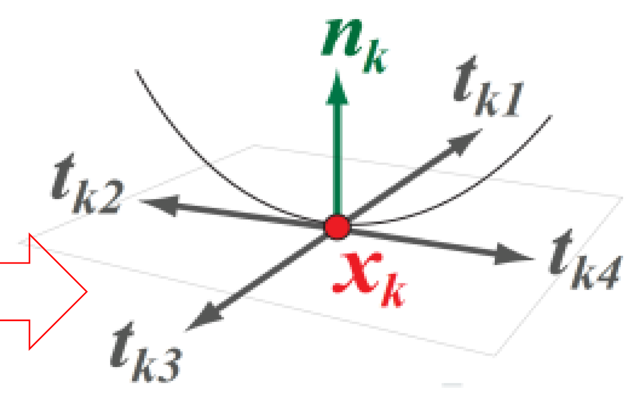
Compare different methods

- Standard equilibrium equations of dynamic deformation

$$\mathbf{M}\ddot{\mathbf{u}} + \mathbf{D}\dot{\mathbf{u}} = \mathbf{r} - \mathbf{f}(\mathbf{u})$$

- Traditional methods with the friction effect

$$\mathbf{M}\ddot{\mathbf{u}} + \mathbf{D}\dot{\mathbf{u}} = \mathbf{r} - \mathbf{f}(\mathbf{u}) + \mathbf{T}_k$$



- Our method

$$\mathbf{M}\ddot{\mathbf{u}} + \mathbf{D}\dot{\mathbf{u}} = \mathbf{r} - \mathbf{f}(\mathbf{u}) + \mathbf{T}_k \quad \Rightarrow \quad update\ \mathbf{u}$$

Update the displacement with friction effect

$$^{t+\Delta t}\mathbf{u} = {}^{t}\mathbf{u} + ({}^{t+\Delta t}\mathbf{x} - {}^{t}\mathbf{x}) = {}^{t}\mathbf{u} + [u_x, u_y, u_z]^T$$

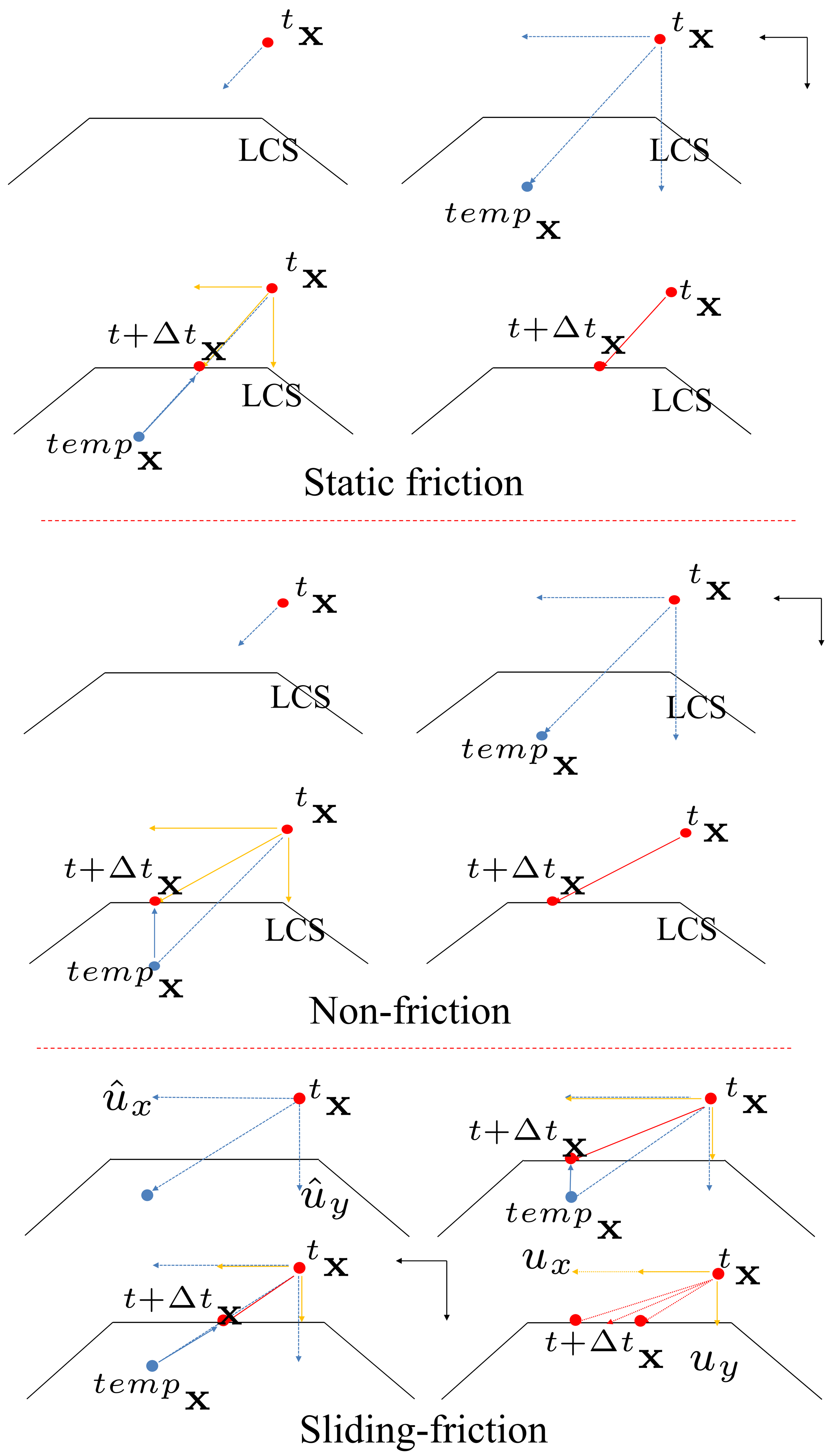
- We define $^{temp}\mathbf{x} - {}^{t}\mathbf{x} = [\hat{u}_x, \hat{u}_y, \hat{u}_z]^T$

$$u_y = distance\ from\ {}^{t}\boldsymbol{x}\ to\ LCS$$

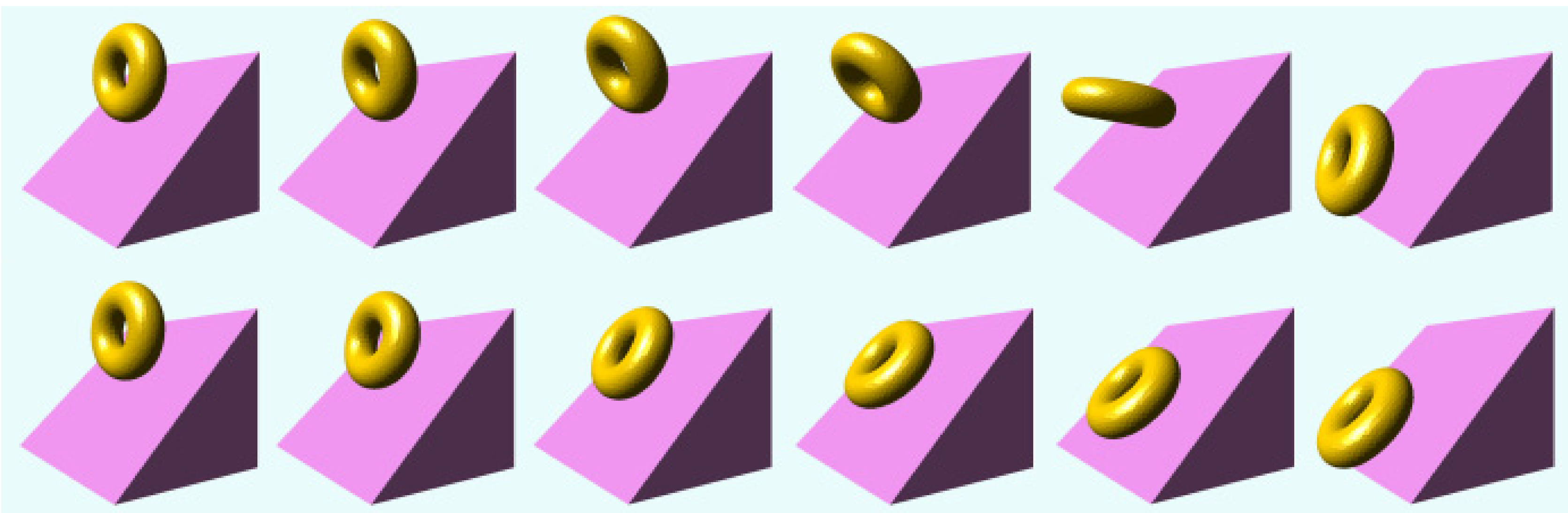
- Update displacement

$$(u_y/\hat{u}_y)\hat{u}_x = u_{xout} \leqslant u_x \leqslant u_{xin} = \hat{u}_x$$
$$(u_y/\hat{u}_y)\hat{u}_z = u_{zout} \leqslant u_z \leqslant u_{zin} = \hat{u}_z$$

Process in different frictional modes

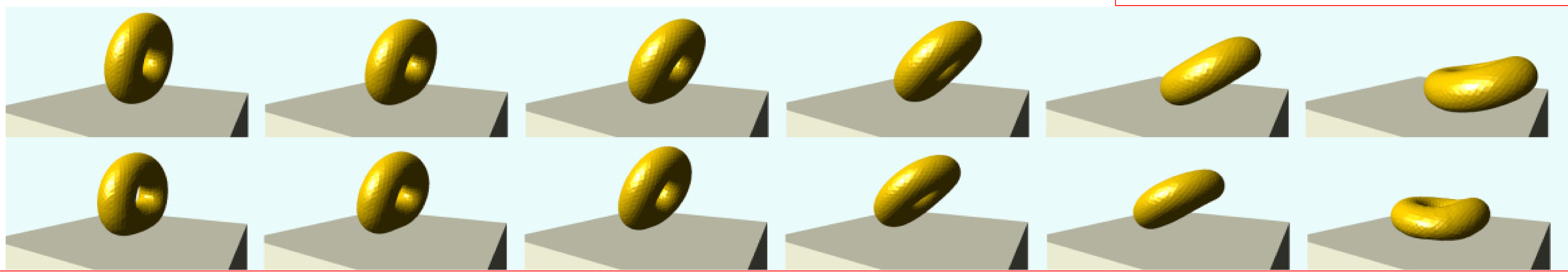


Results



Static friction

Sliding friction



Falling over

Sliding down