Friction Sound Synthesis of Deformable Objects based on Adhesion Theory

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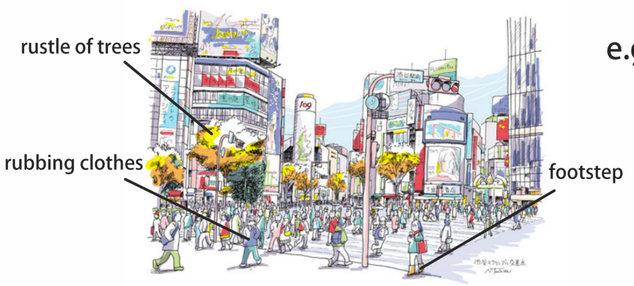
SCA16 symposium on computer animation

1. Introduction

Motivation

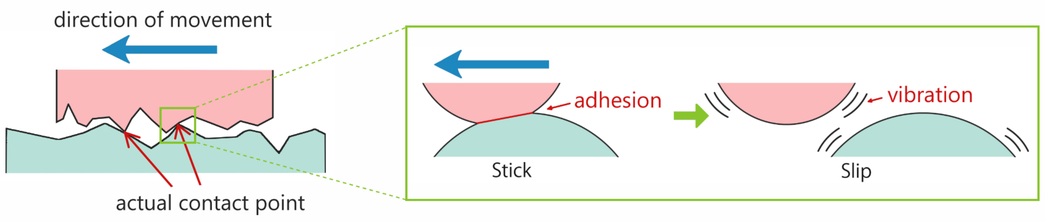
To synthesize friction sounds from deformable objects



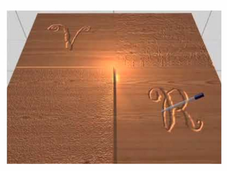
e.g.) familiar sounds
- footstep
- rubbing clothes
- rustle of trees ... etc.

Goal

To synthesize friction sounds with physically-based simulation based on Adhesion Theory



Related Work



using a modal analysis and three phased surface model
- it is difficult to consider non-linear properties

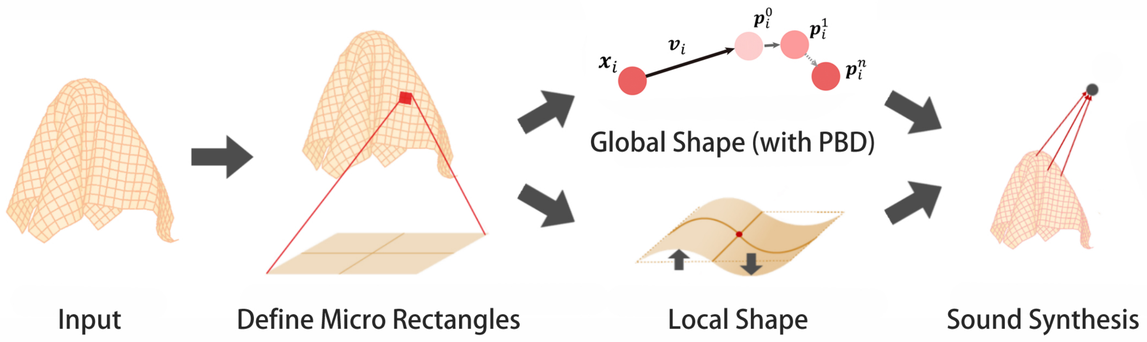
[Ren et al., 2010]

using sound database interpolated sound samples
- the results depend on the quality of databases

[An et al., 2012]

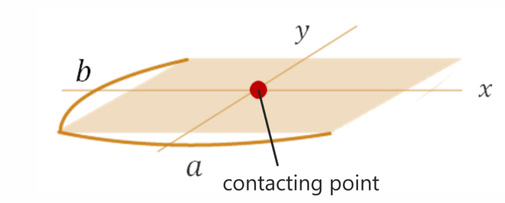
2. Method

Overview



2.1 Define Micro Rectangles

Property of Rectangle



Governing Equation

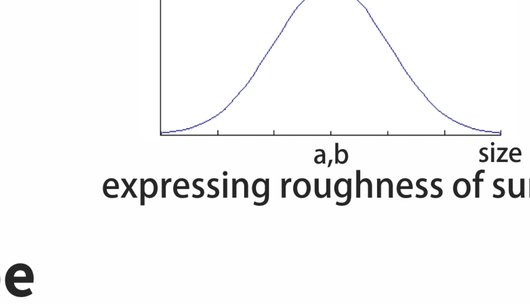
$$D\nabla^4 w + \rho\frac{\partial^2 w}{\partial t^2} = 0$$

D: flexural rigidity
w: displacement
ρ : density of an object

Initial Value of a & b

- size: texture
- distribution: normal

cloth mesh



expressing roughness of surface

2.2 Local Shape

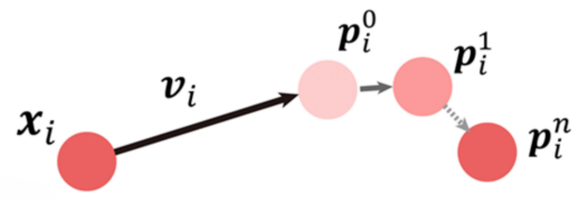
Distorted by friction

The fact: a spectrum of friction sounds depends on the velocity of contacting points

➡ We assume the relation between the size of rectangle and the velocity as below:

$$\frac{1}{a} = \alpha v, \qquad \frac{1}{b} = \beta v \qquad \alpha, \beta: \text{ constant value}$$

2.3 Global Shape



x_i : current position
p_i : modified position
v_i : velocity

modified vector $\Delta p_i = -w_i s \nabla_{p_i} C(p_1, \cdots, p_N)$

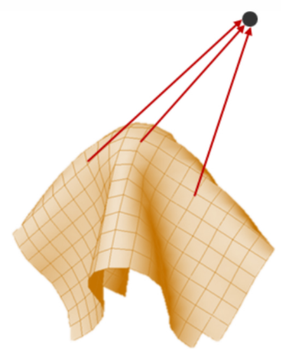
weight · scale · gradient of constraint

$C =$ distant constraint + adhesion constraint

distant constraint: between vertices
adhesion constraint: between other objects

2.4 Sound Synthesis

Synthesizing sounds from contacting points



At the observation point,

$$sound = \sum_i^N P_i(r_i, t)$$

where N is a number of contacting points and P(r,t) is each sound pressure distribution

$$P(r,t) = i\rho c V_0 \frac{k}{4\pi r} e^{-ikr}$$

i: imaginary number
ρ: density of the air
c: acoustic velocity
k: wave number
V_0: vibration velocity of object surface

3. Results

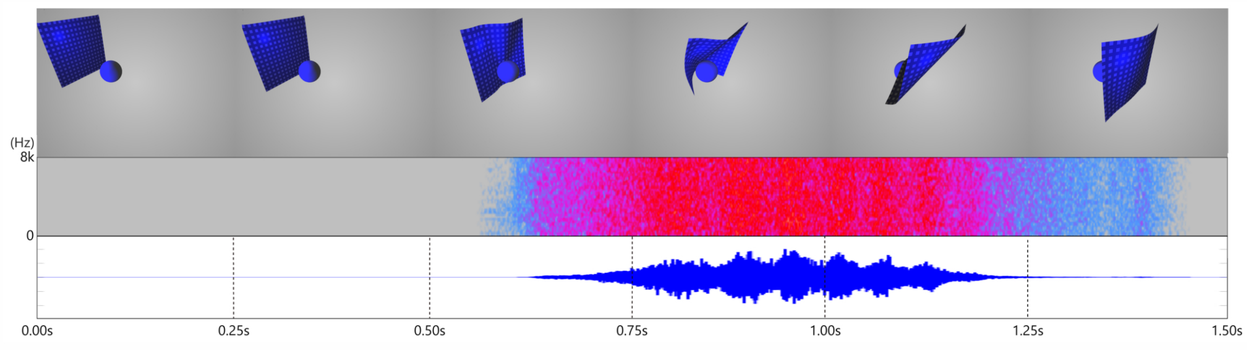
Parameters

	Shear modulus E [GPa]	Poison rate ν	Density ρ [kg/m^2]	a, b [m]	Dispersion σ^2	Vertex	Time [min]
cloth	928.7	0.85	1.54×10^1	5.0×10^{-4}	1.0×10^{-12}	900	31
cooper	129.8	0.343	8.94	1.0×10^{-8}	1.0×10^{-7}	242	72

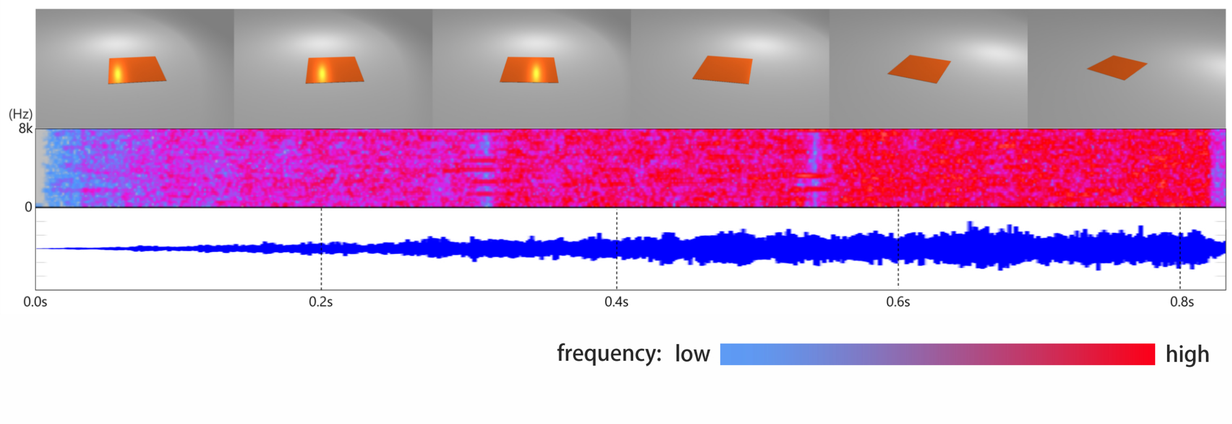
Intel(R) Core(TM) i7 CPU 2.93GHz with 4.0 GB memory and NVIDIA GeForce GT 220

Examples

- cloth: A cotton dragged across a sphere



- metal: A copper sliding on the floor



4. Conclusion & Future Work

Conclusion

We propose a novel approach to synthesizing friction sounds
Our method presents two contributions:
- a capable proposal of wide application from rigid to elastic objects
- subsuming Adhesion Theory into computer animation

Future Work

- Adapting to the complicated scenes and body shapes
- Evaluating the similarity between our results and actual sounds