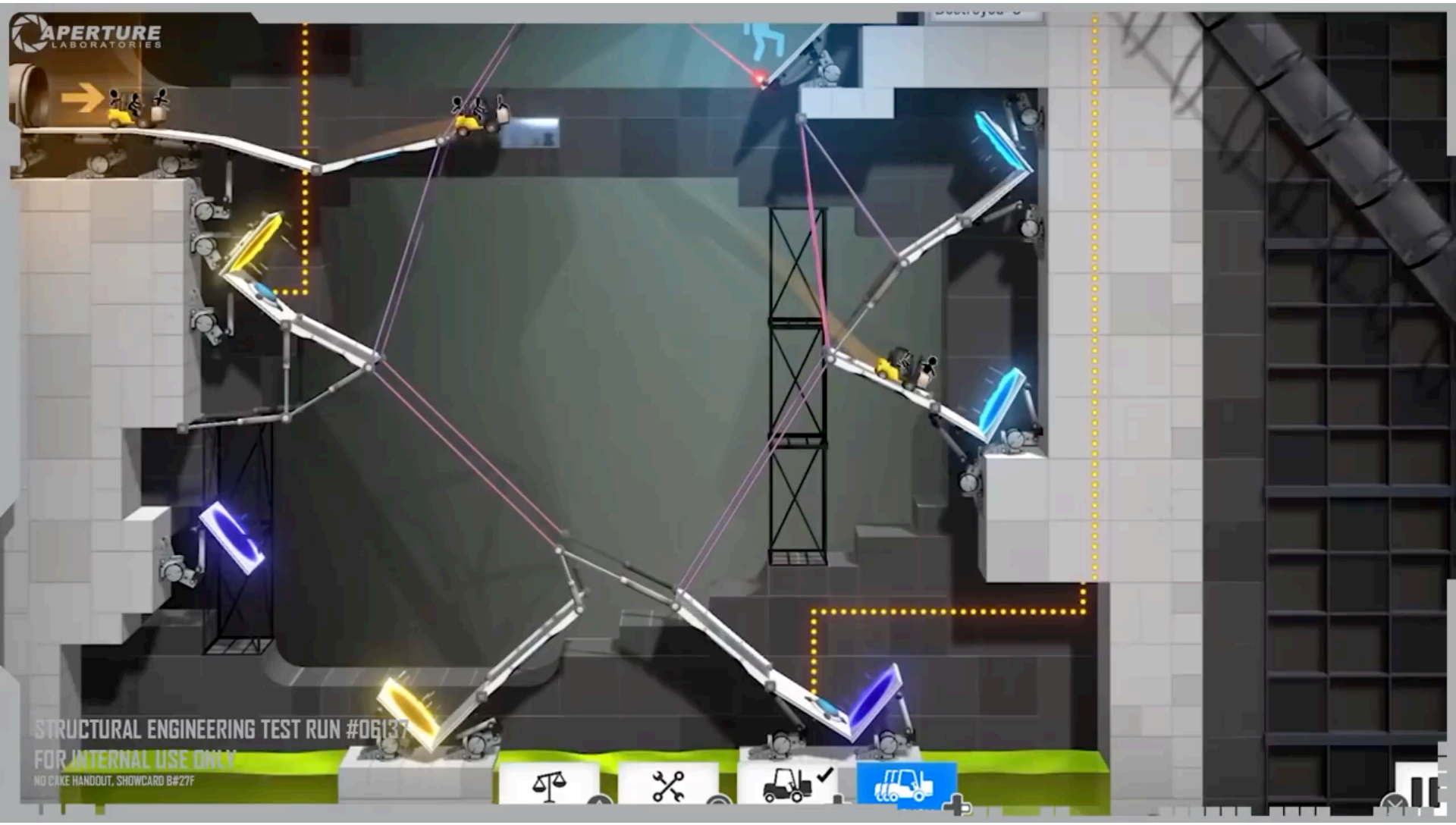
CS 425

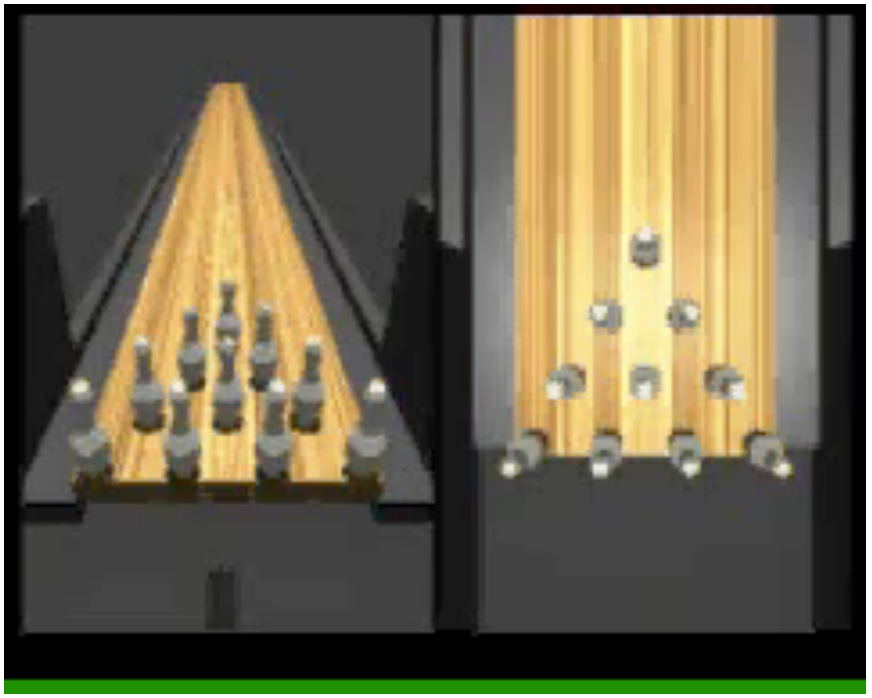
Rigid Body Simulation

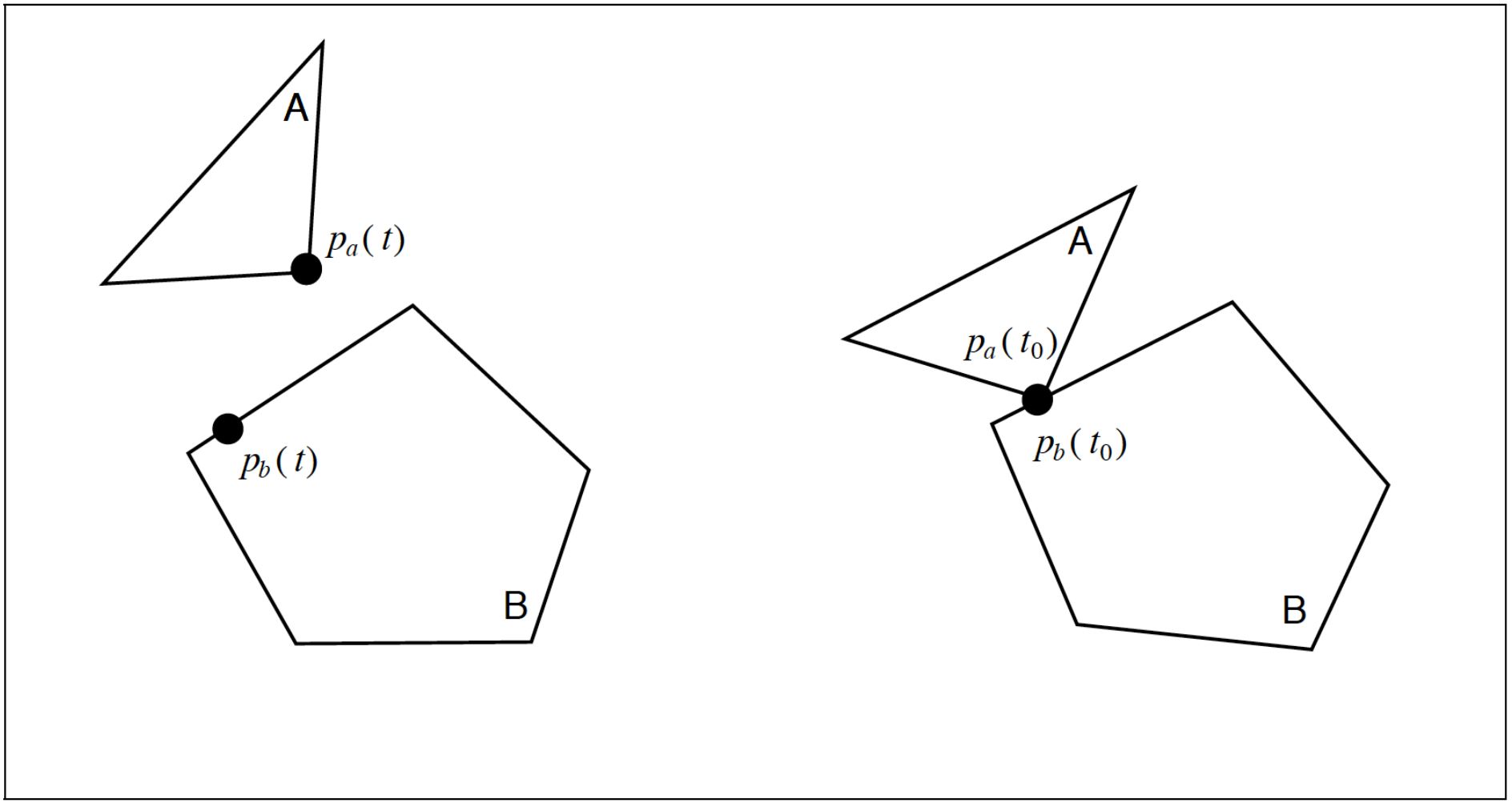
Collision Response and more

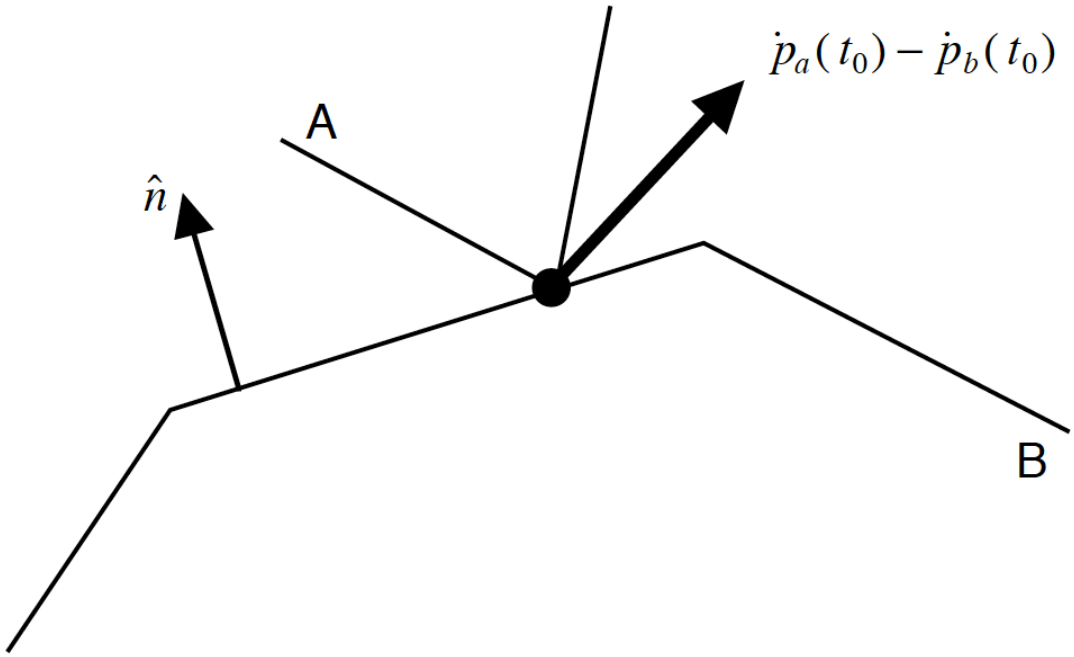
Mass-spring systems

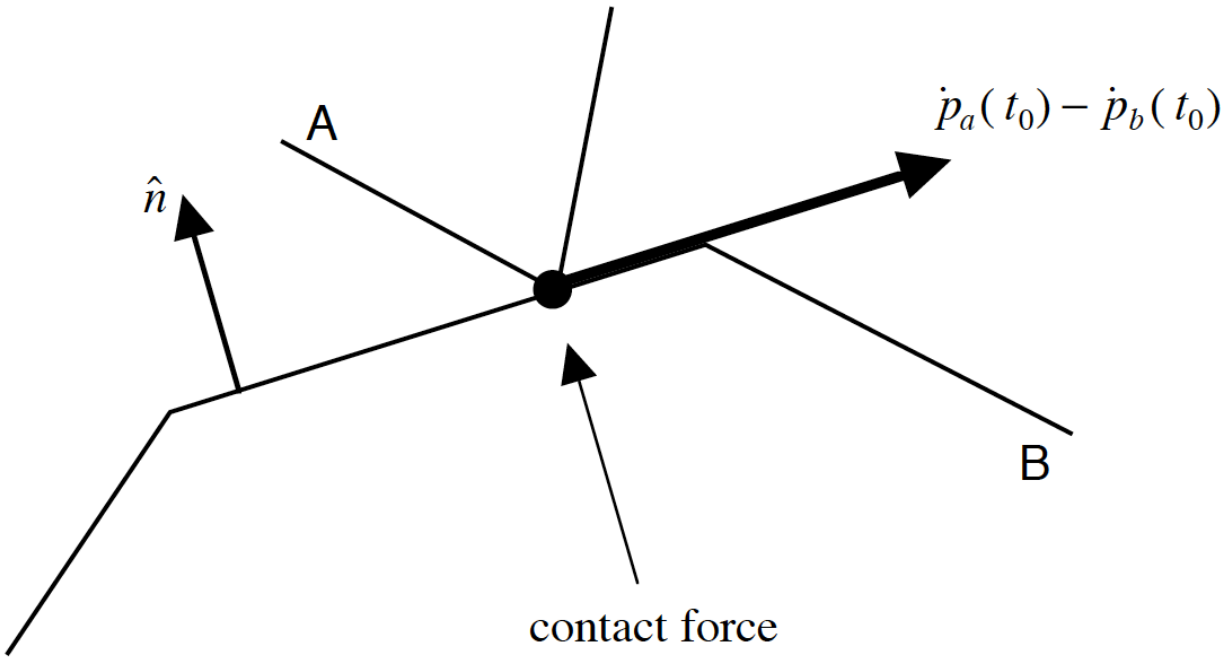

APERTURE
LABORATORIES
STRUCTURAL ENGINEERING TEST RUN #06137
FOR INTERNAL USE ONLY
NO CAKE HANDOUT, SHOWCARD B#27F

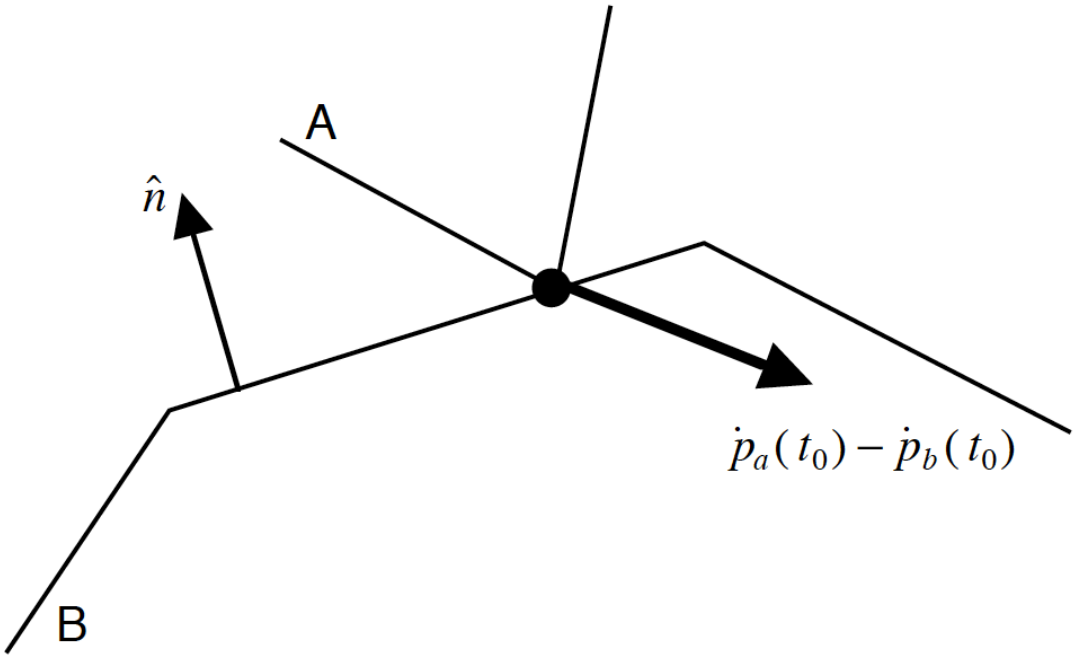
Rigid Body systems




A
$p_a(t)$
$p_b(t)$
B
A
$p_a(t_0)$
$p_b(t_0)$
B

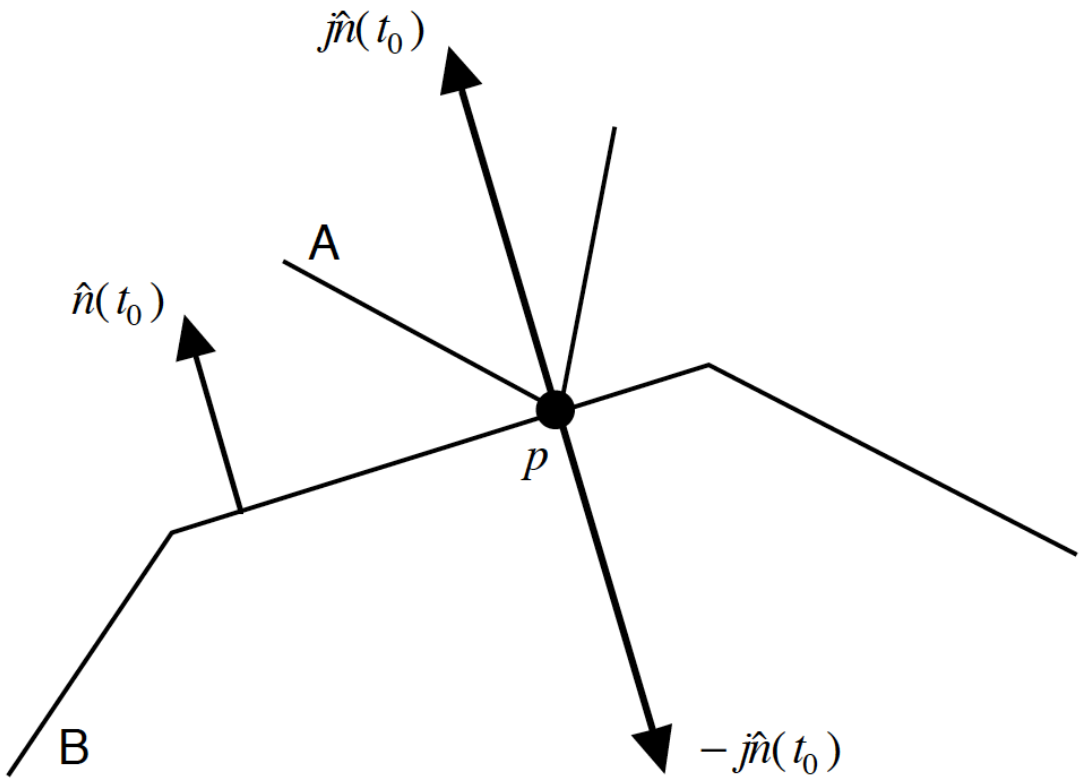

$\dot{p}_a(t_0) - \dot{p}_b(t_0)$
A
$\hat{n}$
B

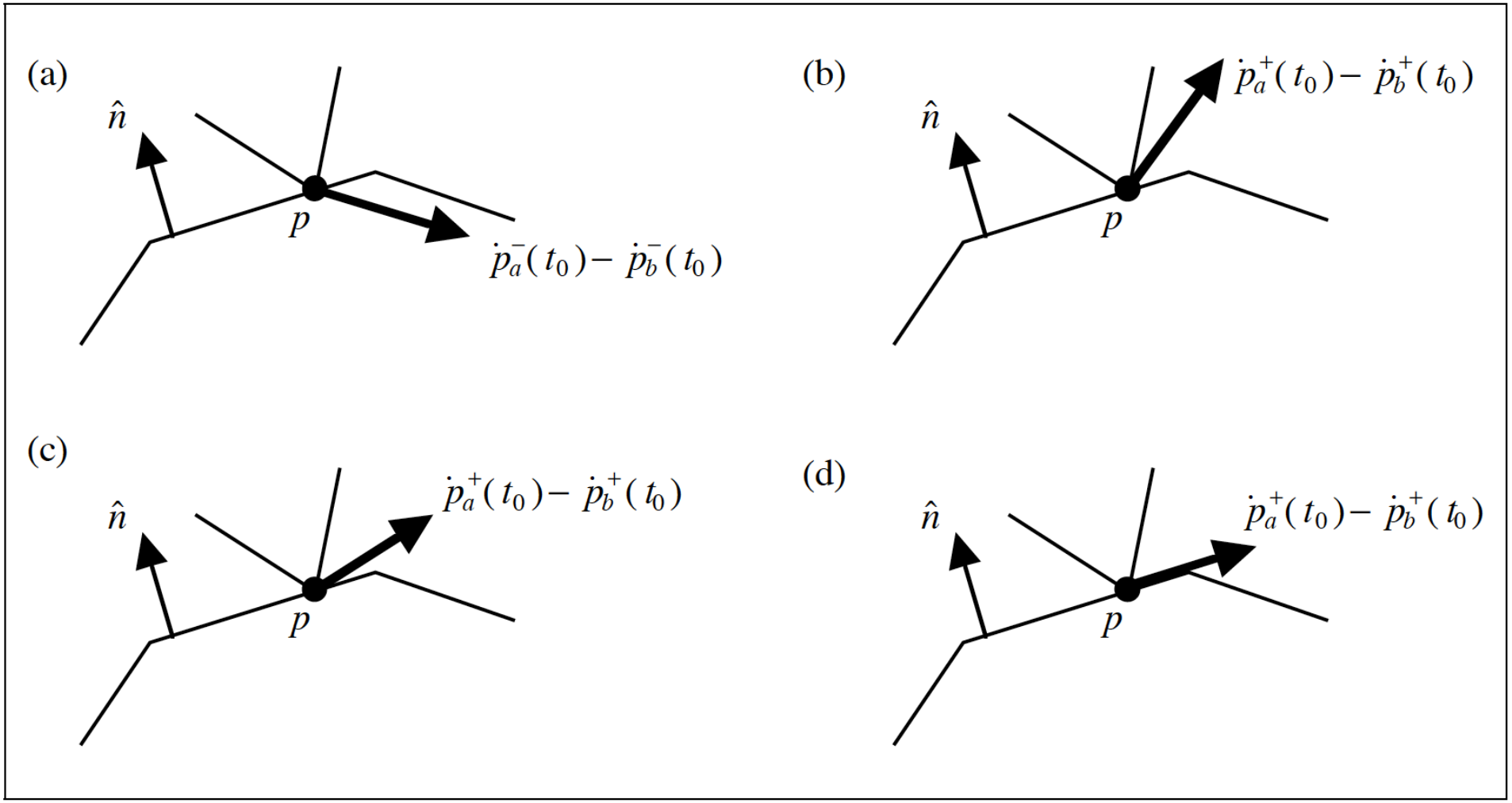

A
$\hat{n}$
$\dot{p}_a(t_0) - \dot{p}_b(t_0)$
B
contact force


A
$\hat{n}$
$\dot{p}_a(t_0) - \dot{p}_b(t_0)$
B

$$j = \frac{-(1+\epsilon)v_{rel}^{-}}{\frac{1}{M_a} + \frac{1}{M_b} + \hat{n}(t_0) \cdot \left(I_a^{-1}(t_0)\left(r_a \times \hat{n}(t_0)\right)\right) \times r_a + \hat{n}(t_0) \cdot \left(I_b^{-1}(t_0)\left(r_b \times \hat{n}(t_0)\right)\right) \times r_b}.$$

$v_{rel}^{-} = \hat{n}(t_0) \cdot (\dot{p}_a^{-}(t_0) - \dot{p}_b^{-}(t_0))$; ϵ is called the *coefficient of restitution*




(a)
$\hat{n}$
p
$\dot{p}_a^-(t_0) - \dot{p}_b^-(t_0)$
(b)
$\hat{n}$
p
$\dot{p}_a^+(t_0) - \dot{p}_b^+(t_0)$
(c)
$\hat{n}$
p
$\dot{p}_a^+(t_0) - \dot{p}_b^+(t_0)$
(d)
$\hat{n}$
p
$\dot{p}_a^+(t_0) - \dot{p}_b^+(t_0)$

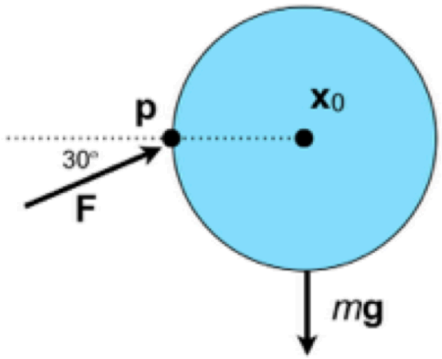
Q1: True or False

Given an arbitrary rotation matrix R

- R is always orthonormal
- R is always symmetric
- $RR^T = I$
- $R_x(30)R_y(60) = R_y(60)R_x(30)$

Q2: Compute this

Consider a 3D sphere with radius 1m, mass 1kg, and inertia $\boldsymbol{I}_{body}$. The initial linear and angular velocity are both zero. The initial position and the initial orientation are $\boldsymbol{x_0}$ and $\boldsymbol{R_0}$. The forces applied on the sphere include gravity (g) and an initial push $\boldsymbol{F}$ applied at point $\boldsymbol{p}$. Note that $\boldsymbol{F}$ is only applied for one time step at t_0. If we use Explicit Euler method with time step h to integrate, what are the position and the orientation of the sphere at t_2? Use the actual numbers defined as below to compute your solution (Let us assume that $g = 9.8$ and $h = 0.1$).



$\mathbf{x}_0 = (0, 0, 0)$ $\quad$ $\mathbf{p} = (-1, 0, 0)$

$\mathbf{R}_0 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$ $\quad$ $\mathbf{F} = (4\cos(30^\circ), 4\sin(30^\circ), 0)$

$m = 1$

$\mathbf{I}_{body} = \begin{pmatrix} 2/5 & 0 & 0 \\ 0 & 2/5 & 0 \\ 0 & 0 & 2/5 \end{pmatrix}$

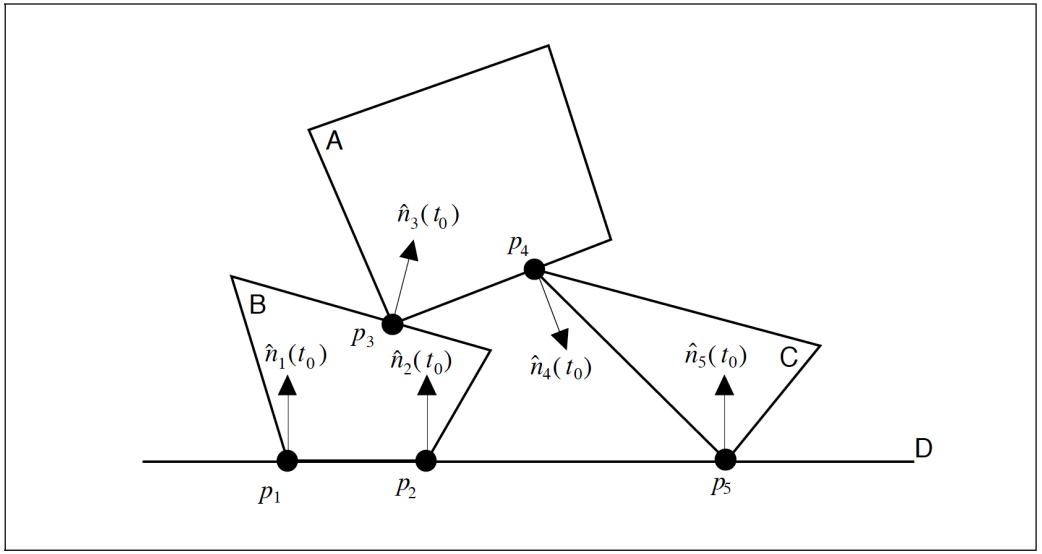
From https://www.cc.gatech.edu/classes/AY2014/cs7496_fall/slides/RigidSim.pdf

Still Want More?

- The lectures from the past few weeks are based on the following notes:
  - Physically Based Modeling: Principles and Practice by Andrew Witkin and David Baraff
  - https://www.cs.cmu.edu/~baraff/sigcourse/

What is still missing?

- Resting contacts



- Frictions
- Penalty-based methods
- ….

David Baraff@Pixar

Available Middleware

- Open Dynamics Engine (ODE)
- Bullet: also open source
- TrueAxis
- PhysX (nVidia)
- Havok: gold standard
- Physics Abstraction Layer (PAL): links multiple physics SDKs
- Digital Molecular Matter (DMM): dynamics of deformable and breakable objects

Major limitations?

- What are the main limitations of the physics modeling?

BD-Tree

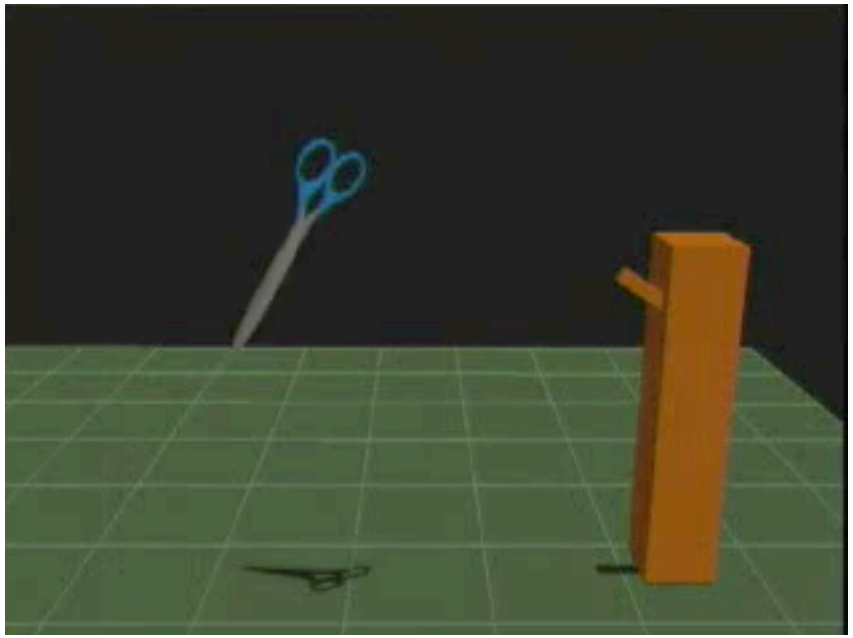
Output Sensitive Collision Detection for Reduced Coordinate Models

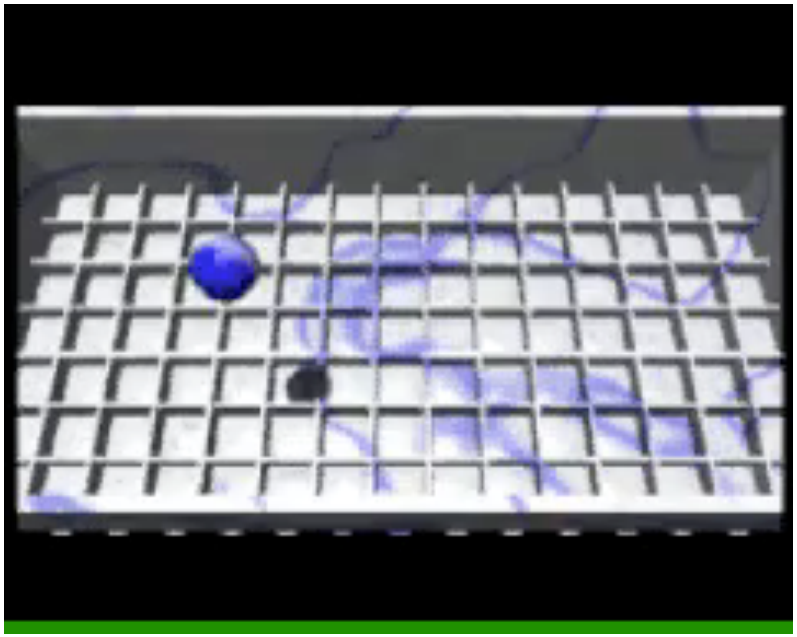
Doug L. James
Carnegie Mellon University

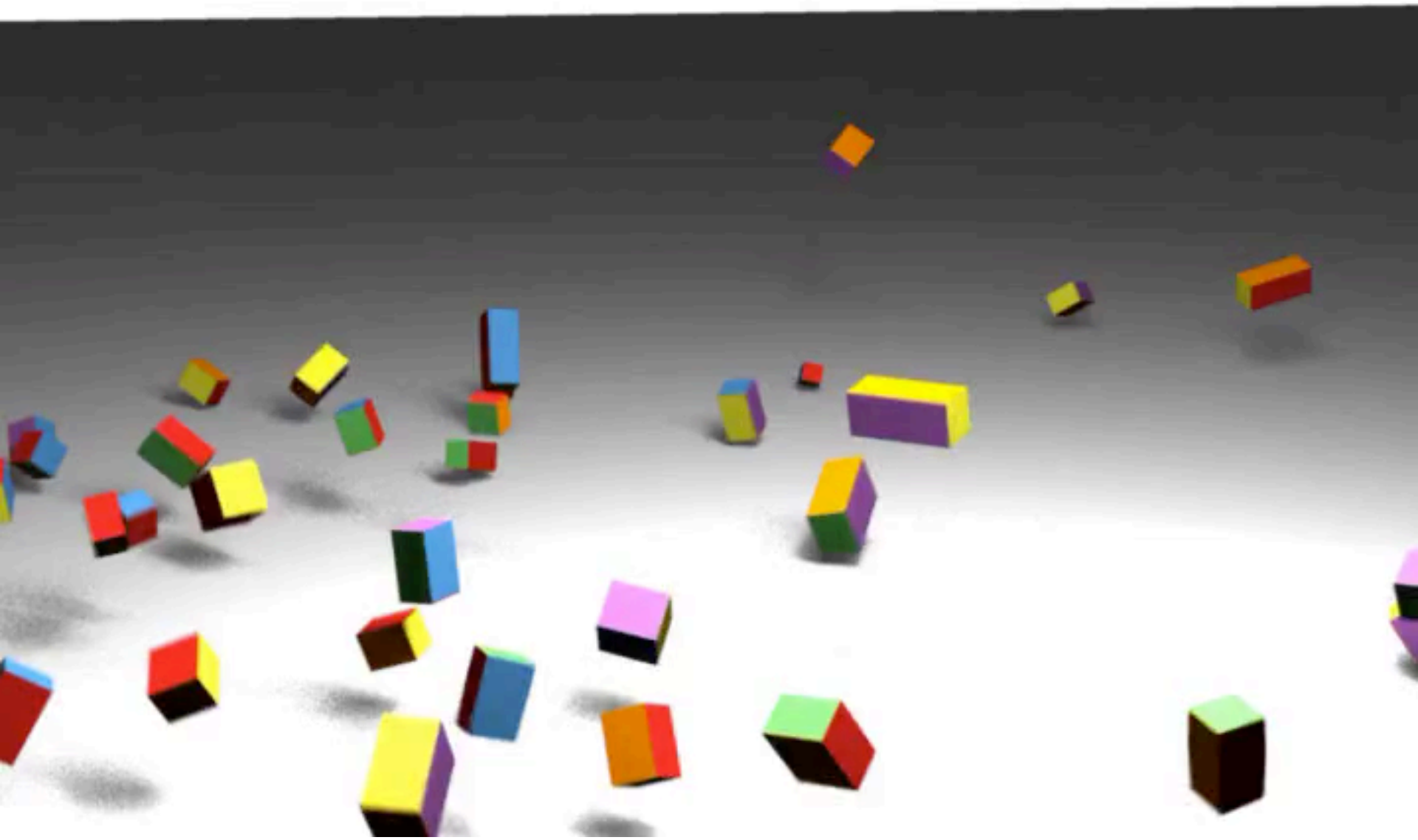
Dinesh K. Pai
Rutgers University


FastLSM:
Fast Lattice Shape Matching
for Robust Real-Time Deformation
Alec Rivers
Doug James
Cornell University

Problems with Physics Simulations in Game/Animations?







When to use physics

- Due to the computational demands of reproducing accurate environments using real physics, it may not be practical to use “heavyweight” physics algorithms all the time.
  - Consider a game that provides a nice animation sequence of a clock face to enhance realism. The clock face plays no part in the game play.
  - Is it worth spending valuable computational time determining the exact position of the hands every frame so the clock tells the PC time?
- Sometimes flat (not even 3D) bitmap based animation sequences will suffice.
  - The player may not even notice the difference.