# Continuous Collision Detection

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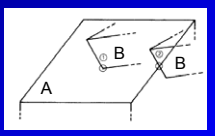
# Classic Collision Detection

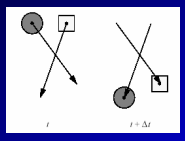
Three cases of elementary collision detection
- Vertex A x Face B
- Vertex B x Face A
- Edge A x Edge B




Discrete Collision Detection
- Evaluates interpenetration at discrete instants of time
- Requires backtracking to compute first contact



# Illustrating the need



No interpenetration at t and t+Δt

- Collision missed if:
  $V_{relative} \times \Delta t > ObjectSize$

=> Smaller time steps, even when it is unnecessary!

Continuous methods detect first contact *during* collision detection



# Need for Robustness

- Backtracking/adaptive time-step helps little
- Three difficult cases:
  - Rapid motion
  - Thin objects
  - Large time-step simulations
- Useful for applications requiring precise, robust simulation of complex objects

# Primitive-Primitive Continuous Tests



# Vertex-Triangle [Provot97]

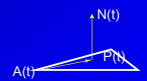
For point *P(t)* and triangle *(A(t), B(t), C(t))* case:

$$AP(t)=uAB(t)+wAC(t)$$

- Non-linear equation

- Optimization using surface normal *N(t)*:

$$AP(t).N(t)=0$$



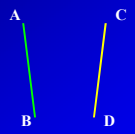

- Cubic equation => determine valid $t_c \in [t, t+dt]$ and find $u, w \in [0, 1]$
- Similar for edge-edge case



# Edge-Edge Primitive

- For edges *AB(t)* and *CD(t)*:

$$A(t) + uAB(t) = C(t) + wCD(t)$$




  - Non-linear equation in *t, u, w*
- Optimization: At $t_c$, *AB(t)* and *CD(t)* should lie in a plane [RKC02]

$$[AB(t)\times CD(t)]\cdot AC(t)=0$$

- Cubic equation => determine valid $t_c \in [t, t+dt]$ and find $u, w \in [0, 1]$



# Applying Continuous Methods to Existing Approaches

# Typical Continuous Algorithm

[ES99, LSW99] uses static BVH at two time steps with continuous primitive tests

[BFA02, RKC02] uses dynamic BVH swept between time steps with continuous primitive tests



# Test Application



# Applications

Precise Virtual Assembly Planning


Courtesy: Stephane Redon [RKC02]

Robust Cloth Simulation

Courtesy: Robert Bridson [BFA02]



# Continuous CD Perspectives

- Collision Response Issue
  - When to apply? $t$, $t_c$ or $t + dt$ ??
- Most effective when combined with traditional approaches
- Applicable for thin, rapid moving objects, precise simulations
- Extra computation cost worthwhile in cases such as above

# References

[RKC02] S. Redon, A. Kheddar and S. Coquillart. Fast Continuous Collision Detection between Rigid Bodies. In *Proceedings of Eurographics*. September 2002.

[MW88] Matthew Moore and Jane Wilhelms. Collision detection and response for computer animation. *ACM Computer Graphics*, 22(4):289-297, 1988.

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[Provot 97] X. Provot, Collision and Self-collision Handling in Cloth Model Dedicated to Design, *Computer Animation and Simulation '97*, pp. 177-190, 1997



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[ES99] J. Eckstein and E. Schomer. Dynamic collision detection in virtual reality applications. In 7th *International Conference in Central Europe on Computer Graphics and Visualization and Interactive Digital Media*, pages 71-78, 1999

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[BFA02] R. Bridson, R. Fedkiw, and J. Anderson. Robust treatment of collisions, contact and friction for cloth animation. In *Proceedings of SIGGRAPH '02*, pages 594-603. ACM Press, 2002.



# Thank You!

*Bastille, Grenoble*

http://www-evasion.imag.fr



# Questions/Comments?