
6-DOF HAPTIC RENDERING

Zhen Shao



6-DOF vs 3-DOF

- * 3-DOF: point, position, force
- * 6-DOF: object, position & orientation, force & torque

Friday, October 22, 2010

3DOF haptic rendering: virtual object A, 3D position $p(\text{input}) \Rightarrow$ contact point p' (on A), contact force f (based on p, p').

6DOF haptic rendering: virtual object A, virtual object B(pos, ori \leftarrow input) \Rightarrow multiple contact points, force and torque

Haptic Rendering Pipeline

- * direct rendering
- * virtual coupling

Friday, October 22, 2010

short review, in case that Pete doesn't make it clear.
advantages & disadvantages of each

Ideal and Practical

- * ideal solution:
 - * position: constraint-based rigid body dynamics simulation
 - * force-feedback: virtual coupling
- * practical

Direct Rendering Approaches

- * Gregory et al. 2000, Kim et al. 2003
- * Johnson and Willemssen 2003, 2004, Johnson and Cohen 2001, Nelson et al. 1999

(Gregory et al. 2000)

6-DOF haptic display of polygonal models

- * can be used on moderately complex polygonal models
- * convex decomposition
- * predictive collision response(fast update)
- * force and torque interpolation

(Kim et al. 2003)

6-DOF haptic rendering using incremental and localized computations

- * localized contact computation: guaranteed by high motion coherence due to fast force update & spatial locality near contact regions
- * decompose surface, build hierarchies for fast proximity queries
- * incremental method to estimate penetration depth
- * clustering nearby contacts to speed up force determination

(Johnson and Willemssen. 2004)
**Accelerated haptic rendering of polygonal
models through local descent**

- * local minimum distance(LMD) and spatialized normal cone hierarchies(SNCH)
- * maintaining LMDs between models during movement
- * each LMD less than cutoff distance is considered as a spring.

Virtual Coupling with Object Voxelization

- * McNeely et al. 1999
- * Renz et al. 2001
- * Wan and McNeely 2003

(McNeely. 1999)

6-DOF haptic rendering using voxel sampling

- * enable manipulation modestly complex rigid object within an arbitrarily complex environment of static rigid object
- * global voxel size, voxmap
- * impedance-device and virtual coulper scheme
- * penalty based

(Wan and McNeely. 2003)

Quasi-Static Approximation for 6-DOF haptic rendering

- * Quasi-static approximation (QSA)
- * solve for static equilibrium during each haptic time step
- * stable

Rigid Body Dynamics with Haptic Feedback

- * Impulse Dynamic Rigid Body Simulation

- * Chang and Colgate 1999

- * Constantinescu et al. 2004

- * Constraint Based Rigid Body Simulation

- * Berkelman 1999

- * Ruspini and Khatib 2000

- * Penalty Based Relaxed

- * McNeely et al. 1999

- * Wu 2000

- * Larsen 2001

- * Otaduy and Lin 2005

(Chang and Colgate. 1997)
**Real-time Impulse-based simulation of rigid
body systems for haptic display**

- * based on virtual coupling(Colgate et al. 1995)
- * based on impulse-based simulation
- * heap of time-to-collide estimation, integration

(Ruspini and Khatib. 2000)
The haptic display of complex graphical environments.

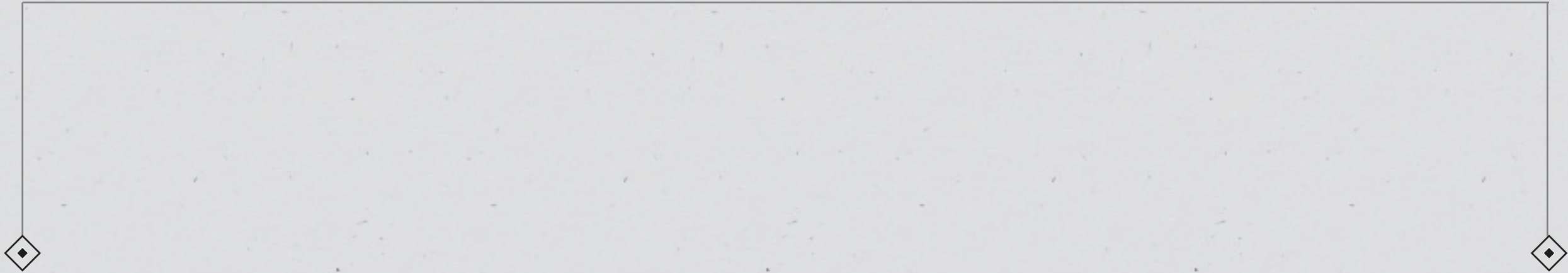
- * using standard constraint-based position updating algorithm
- * friction
- * based on Baraff 1992

Multi-resolution (LOD) Techniques

- * Otaduy and Lin 2003
- * Otaduy 2004

Recent Publications

- * Kolensnikov and Zefran 2007 (penalty)
- * Otaduy and Lin 2006 (penalty, LOD, linearized model)
- * Barbic and James 2009(penalty, LOD, deformable)



* Thank you.