Combining Geometric Constraints with Physics Modeling for Virtual Assembly using SHARP

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Outline

- Motivation
- Background
- Initial Approach
- Physical Constraint Simulation
- Geometric Constraint Modeling
- Case Studies
- Summary & Future Research

What is Virtual Assembly ?

The ability to assemble CAD models of parts

using a three-dimensional immersive user interface and natural human motions

Virtual Assembly at C6 in VRAC[1]

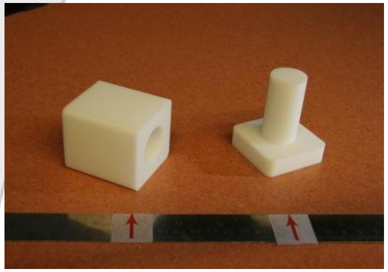
1 Photo courtesy: Chang-Eun Kim

Motivation

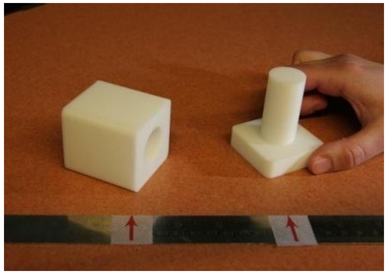
- Accounts for human-interactions in a simulation
- Faster identification of problems in the design
- Faster product development
- Time & cost savings
- Training assembly workers
  - Offline training
  - Capture expert assembly methods from experienced workers to guide training
- Collaborative assembly

http://www.ceit.es/mechanics/projects/Revima/Revima.htm

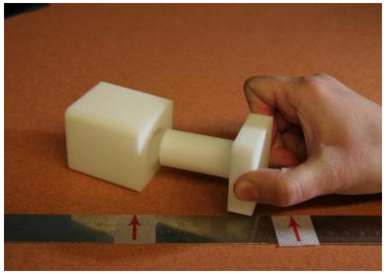
Sample Assembly Task



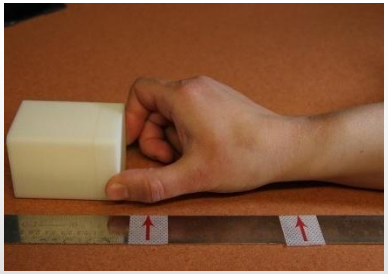
Realistic
Representation



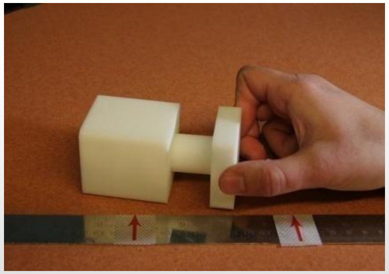
Tactile Force Feedback
Depth Perception



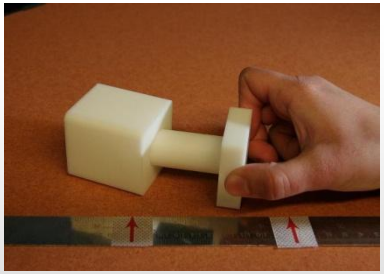
Dexterous & Intuitive
Manipulation



Realistic Part Behavior



Realistic Part Behavior
Collision + Tactile force feedback
Precise Part Manipulation



Simulating Physical
Constraints

Previous Research in Virtual Assembly

Positional Constraints (Snapping)

- Kuehne, R. et al., 1995
- Carpenter, I.D. et al., 1996

Geometric Constraints

- Jayaram, S. et al. VADE, 1999
- Marcelino , L. et al., 2003
- Wan, H. et al., MIVAS, 2004
- Jun, Y. et al., 2005

Physical Constraints

- McDermott, S. & Bras, B., HIDRA, 1999
- Kim, C-E. & Vance, J.M., NHE, 2003
- Seth, A. & Vance, J.M., SHARP, 2006

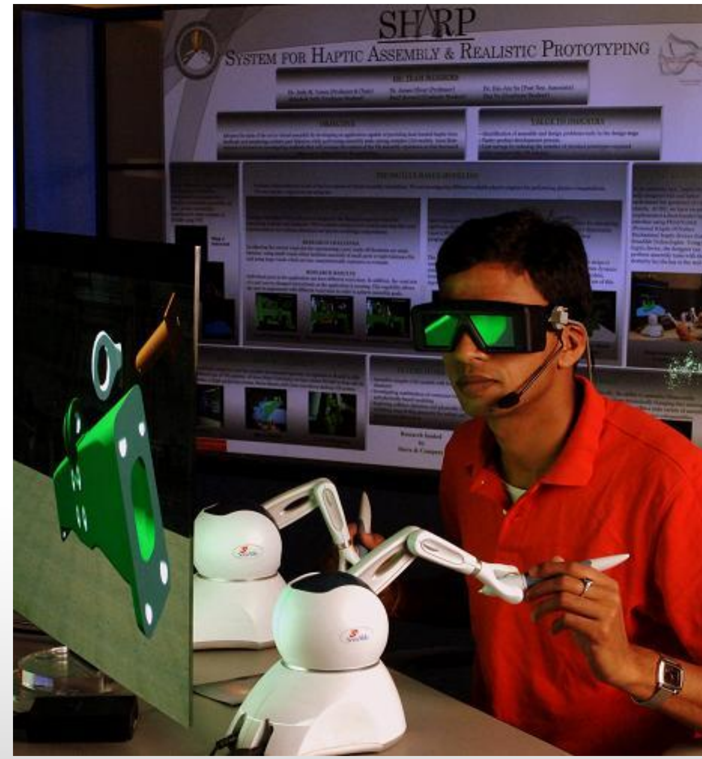
Physical + Geometric Constraints

- Wang, Y. et al., VADE, 2001

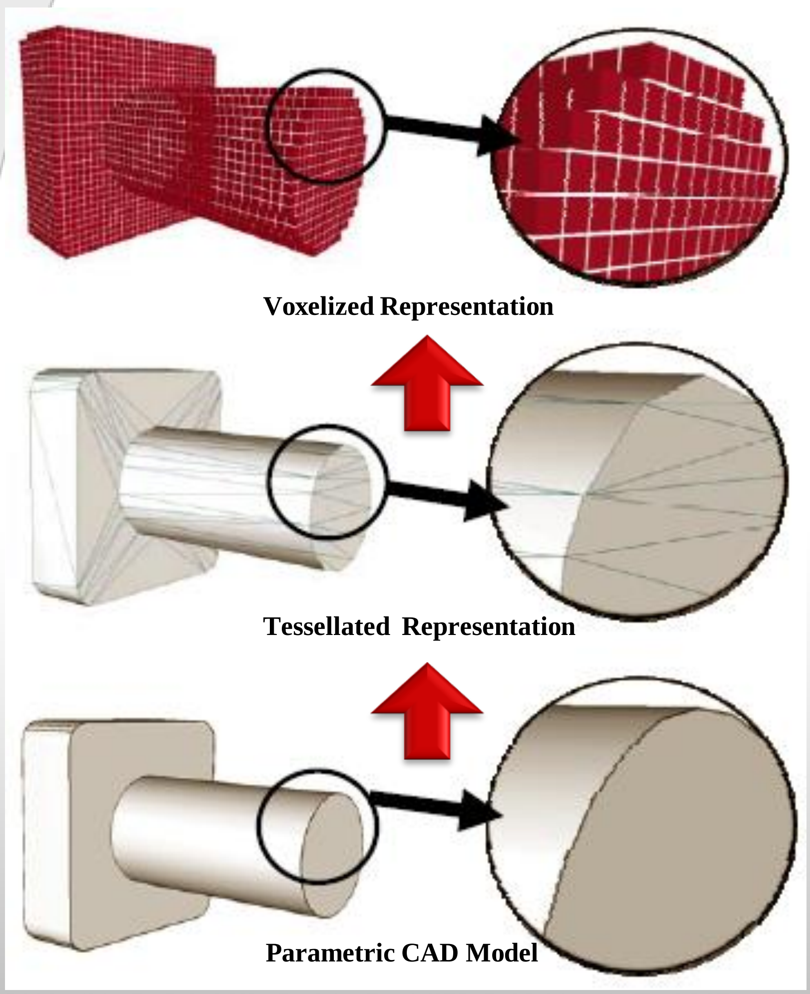
SHARP

System for Haptic Assembly & Realistic Prototyping

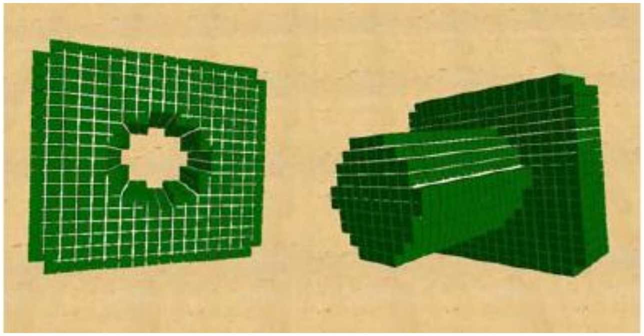
- Collision detection
- Physical constraints
- Dual-handed haptic interface
- Complex CAD model assembly
- Subassembly support
- Swept volumes
- Network communication
- Portable to different VR Systems



Physics-based Modeling in SHARP (2006)



Voxel, tri-mesh and B-Rep representations of a model

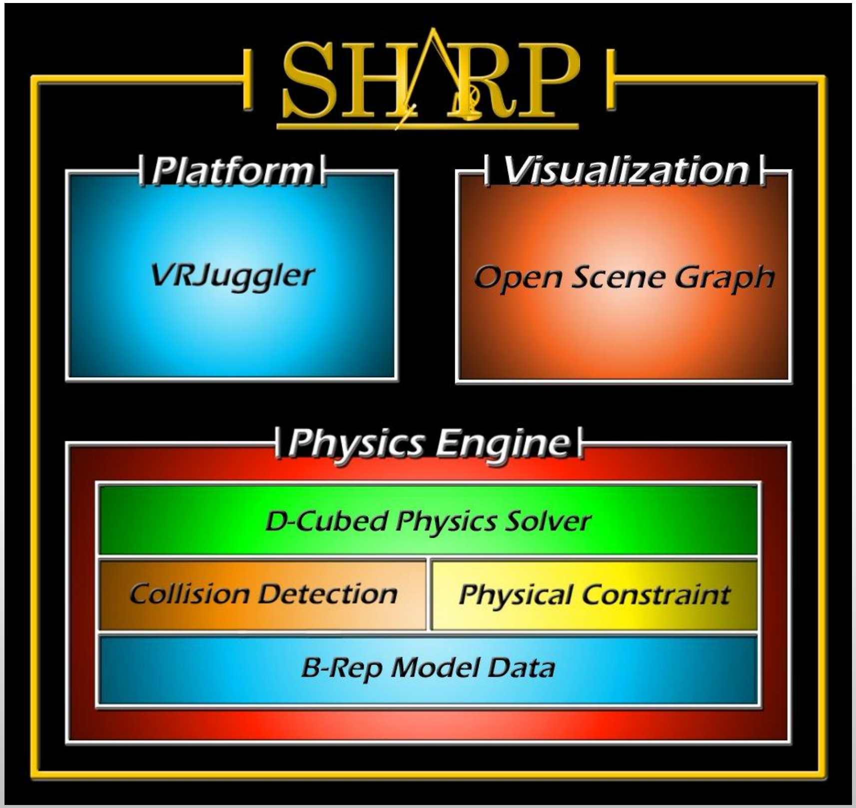


Voxel Model Representation for Pin & Hole Model

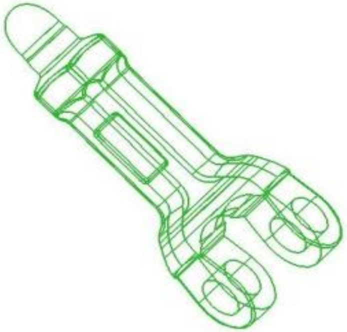
- Limitations
  - CAD model approximation using voxels
  - Low clearance assembly not possible
  - System insensitive to features smaller than voxel size
  - Large and small part assembly not possible
  - High memory & computation requirements
  - Limited number of parts in the environment

B-Rep Based Physical Constraints

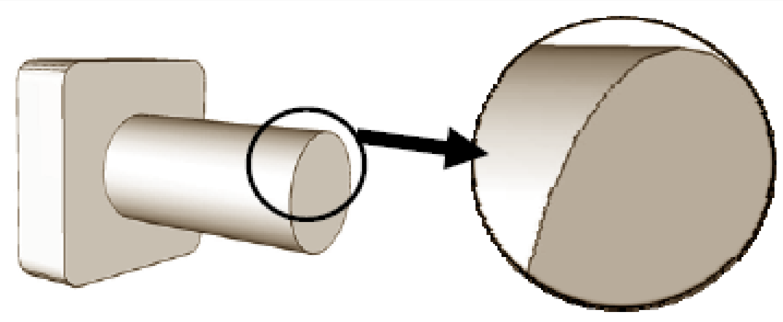
- Precise CAD model representations (B-Rep)
  - Collision detection
  - Physics-based modeling



Graphic Model



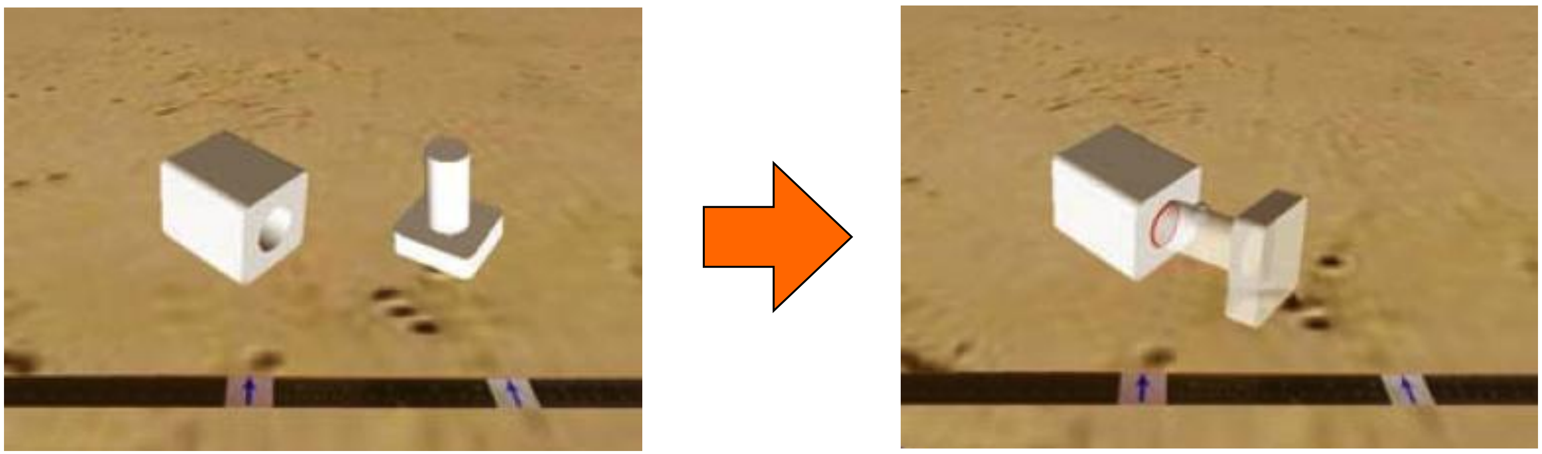
B-Rep Model



Parametric model representations in SHARP

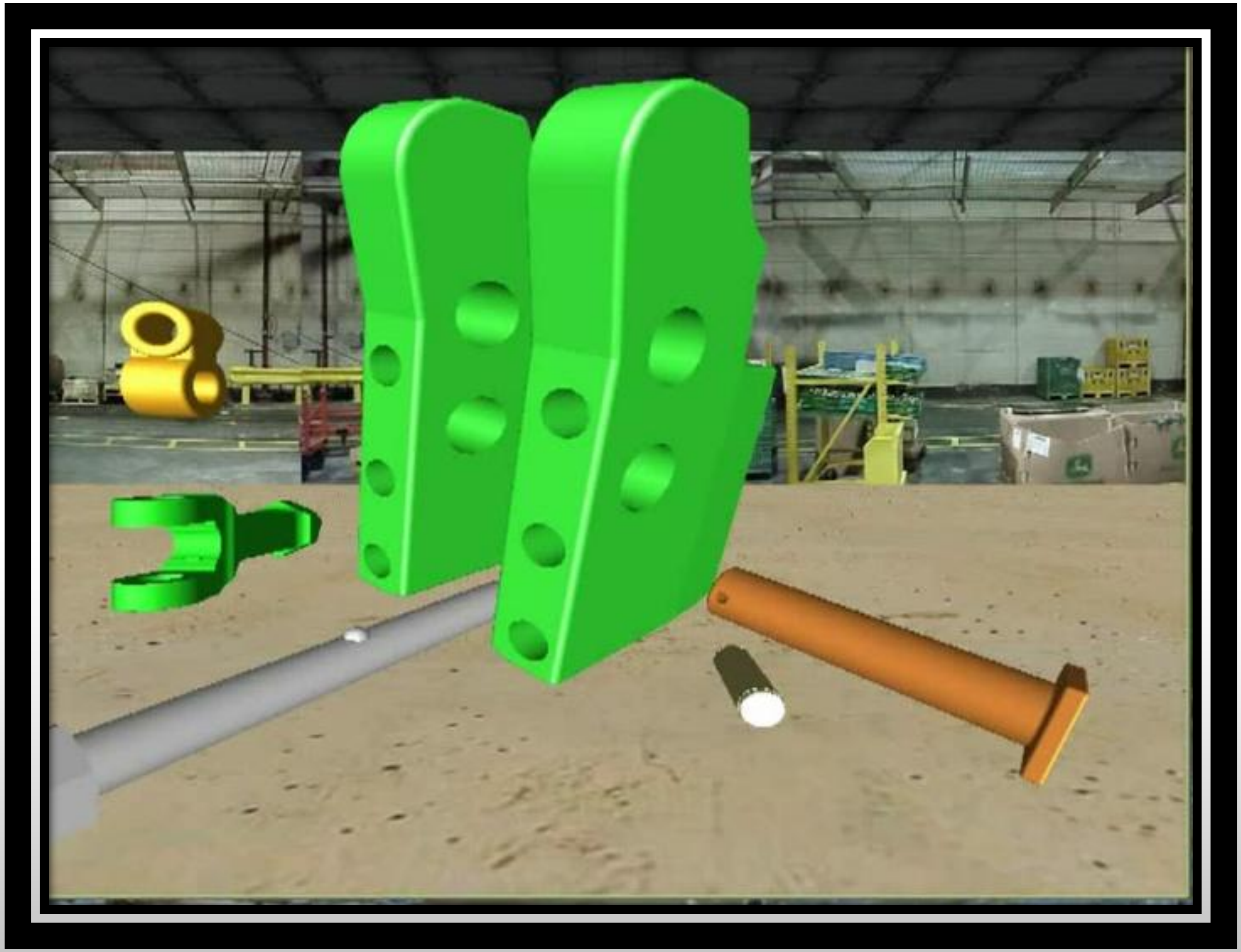
B-Rep based Physical Constraints

- Case 1 - Collision Only



- Case 2 – Collision + Physical Constraints
  - Successfully simulate realistic part behavior
  - Difficult to assemble low clearance parts with very small clearance
  - Precise part movements in virtual environment can't be achieved

Physical Constraints during Assembly



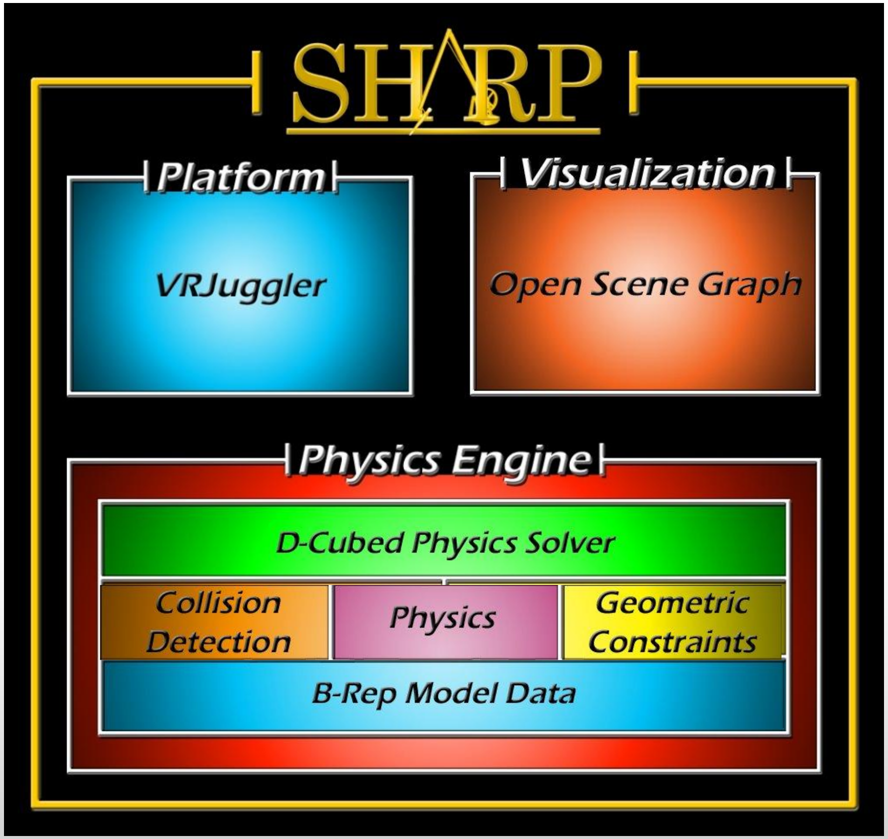
Constraint-Based Modeling

- Uses predefined relationships among geometric features
- Limits degree-of-freedom of a part
- Simplifies assembly operation

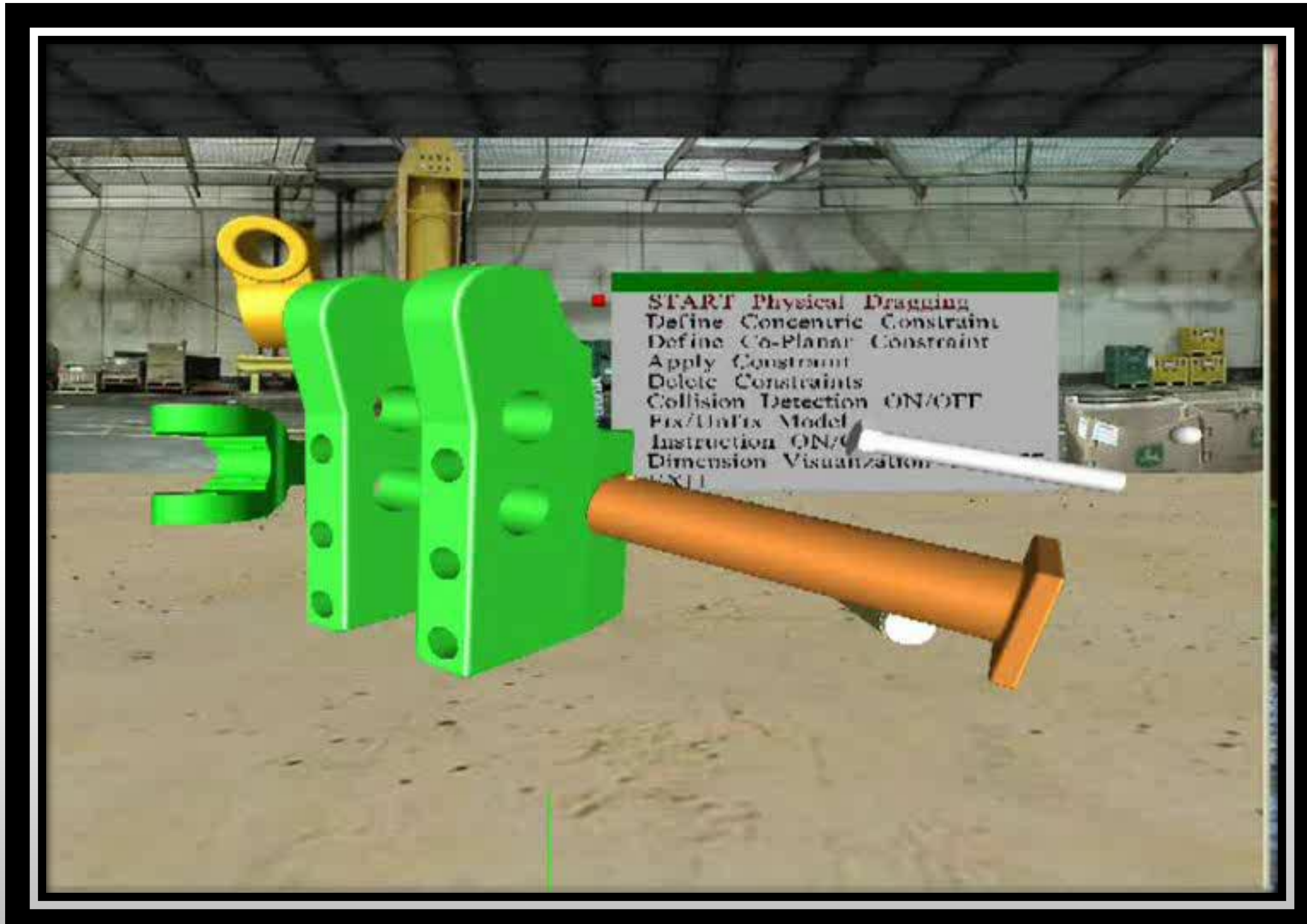
	Constraint-Based Modeling	Physics-Based Modeling
Low Computation Load	X	
Precise Part Movement	X	
Prevent Part Interpenetration		X
Realistic Behavior Simulation		X

Combining Physical & Geometric Constraints

- Constraint Module
  - Define geometric relationships
  - Precise part manipulation
- Voice Module
  - Voice recognition
  - Feedback
- Hybrid Approach
  - Collision detection
  - Physical constraints
  - Geometric constraint-based modeling

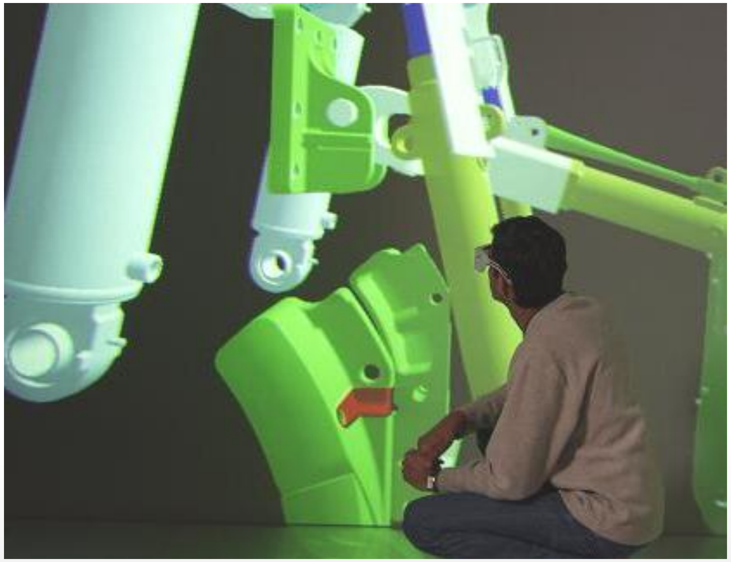


Assembly using Hybrid Approach



Conclusions & Future Work

- A hybrid approach facilitates realistic simulation of manual assembly tasks in virtual environments
- SHARP system demonstrates
  - Realistic part behavior & interaction
  - Highly accurate collision/physics responses
  - Runtime geometric and physical constraints
  - Access to accurate parametric data in VR



SHARP running in a six-sided CAVE System

- Future Work
  - Automatic constraint recognition
  - Haptic rendering while preserving simulation accuracy

Acknowledgements

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Thank You !