Design and Virtual Reality

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National Science Foundation

Outline

Virtual Reality Applications Center Research

- Mechanism Design
- Interactive Stress Analysis
- Ergonomic Design
- VR Assembly
- Other Projects

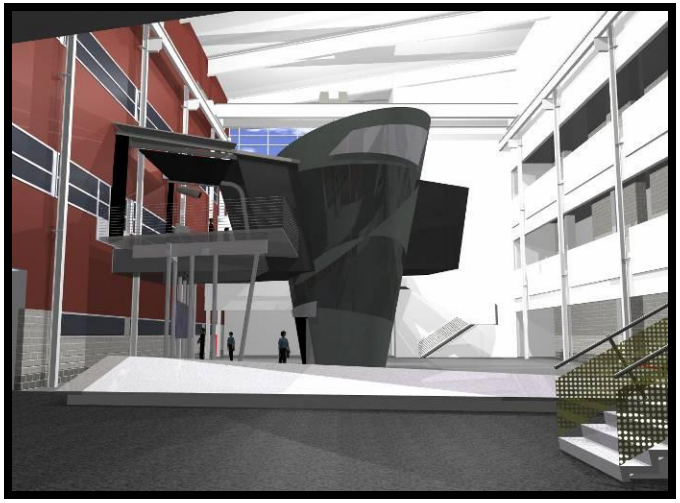
Virtual Reality Applications Center

To be a national leader in the application of virtual reality to the challenges of science and engineering

VRAC

- 15 million USD in contract funding
- 35 active interdisciplinary projects
- 40 faculty investigators from 7 colleges
- 180 graduate and undergraduate researchers
- Sponsors
  - National Science Foundation
  - Industry
  - Government

VRAC Facilities



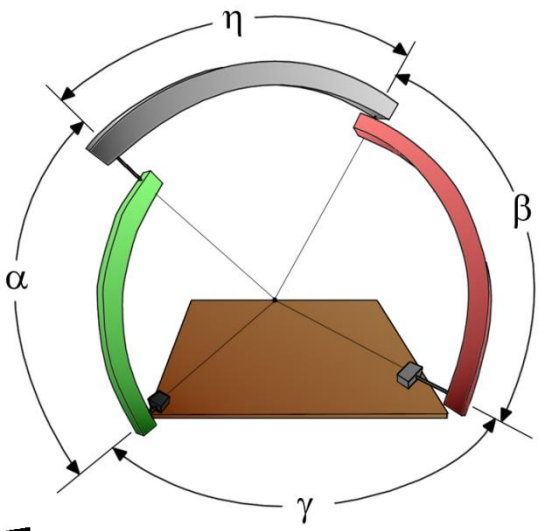
Applications Focus

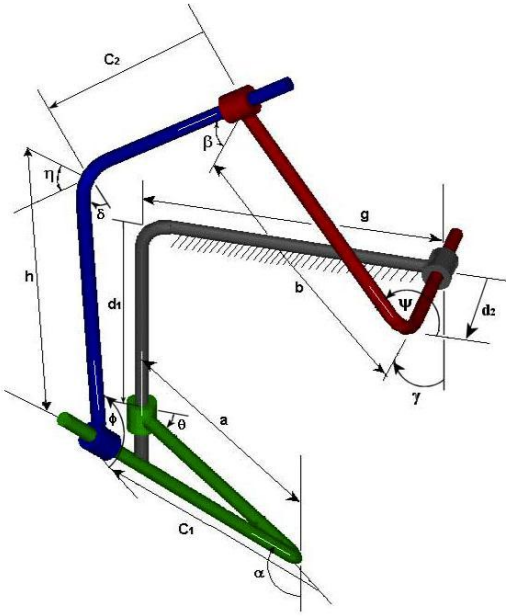
"Virtual"

- Simulations
- Immersion
  - Stereo viewing
  - Position tracking
  - Haptics
  - Sound

Mechanism Design Using Virtual Reality

To develop new and innovative methods to design spherical and spatial four-bar mechanisms based on the use of virtual reality technology





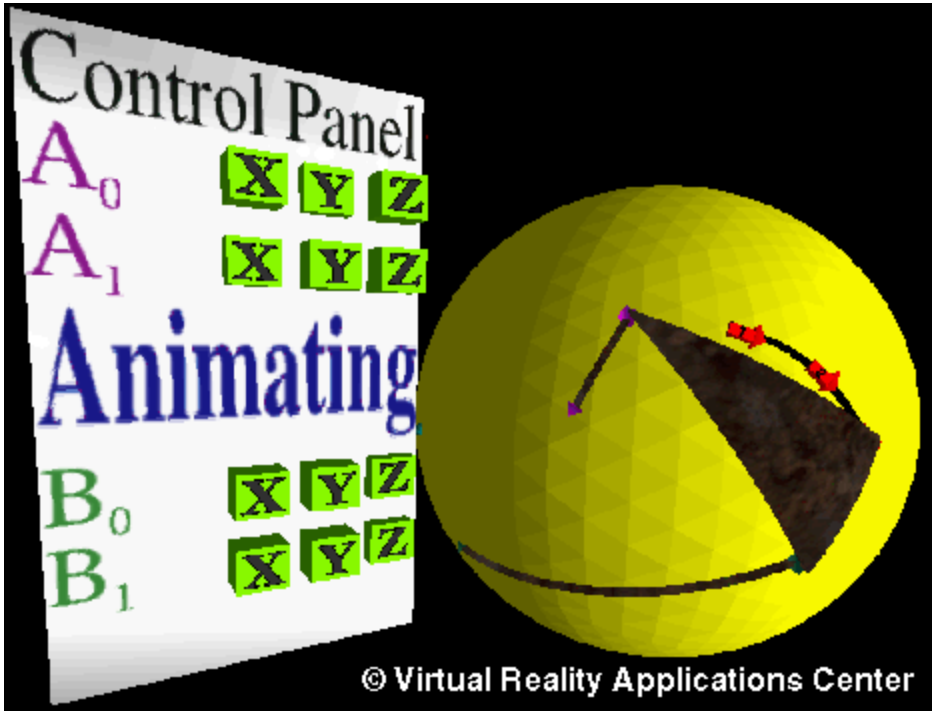
Motivation

Spatial mechanisms offer a feasible alternative to electronically controlled multiple-input devices such as robotic manipulators

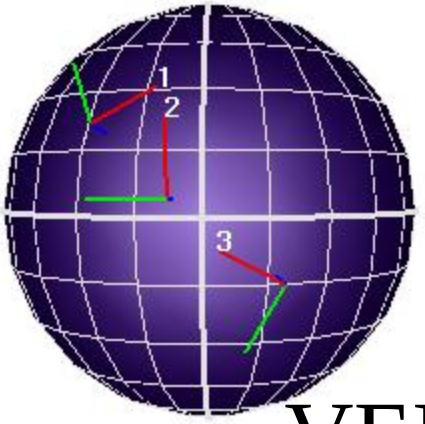
These mechanisms operate within three-dimensional (3D) design space and therefore, the use of three-dimensional interfaces should improve our ability to design optimal mechanisms.

Spherical Mechanism Design

SphereVR

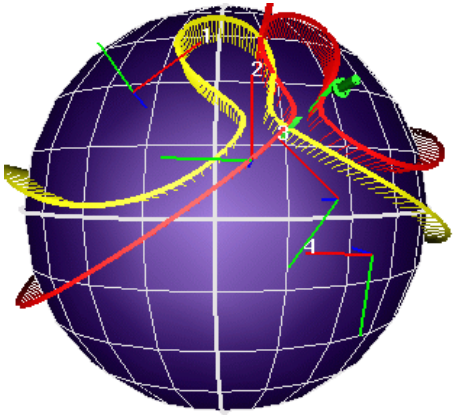


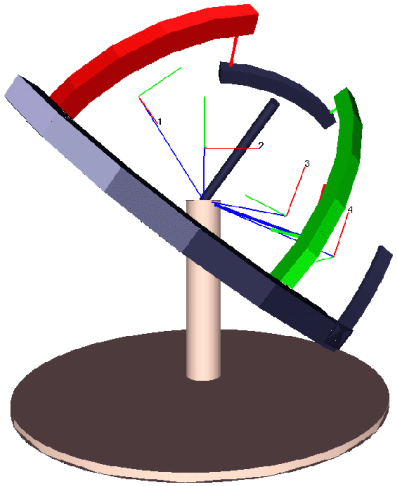
Osborn, S.W. and Vance, J. M., "A virtual reality environment for synthesizing spherical four-bar mechanisms," *ASME Design Automation Conference Proceedings*, Boston, MA, September 17-21, 1995, Vol. DE-83, pp. 885-892.

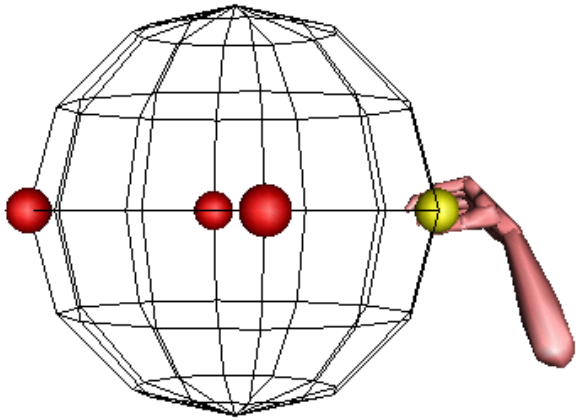


VEMECS

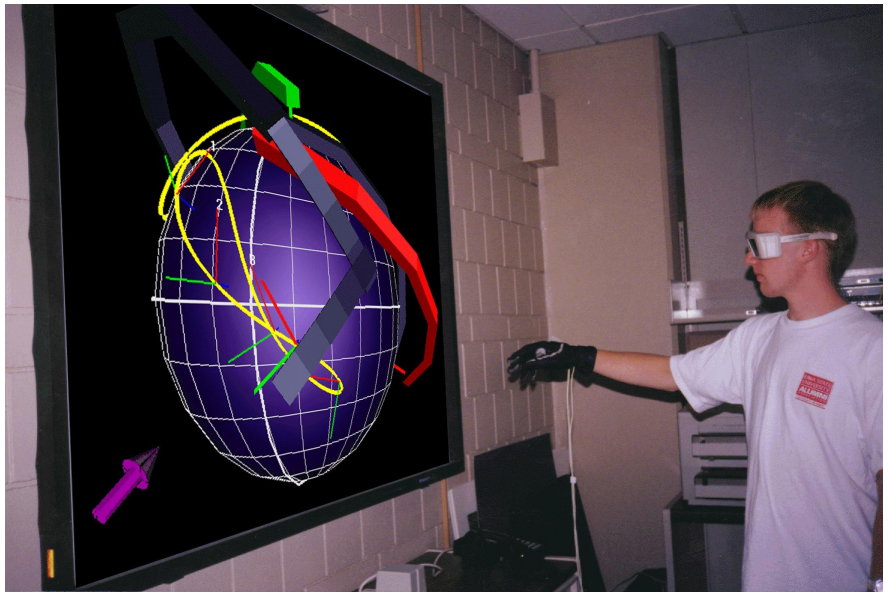
Virtual Environment MEChanism Synthesis



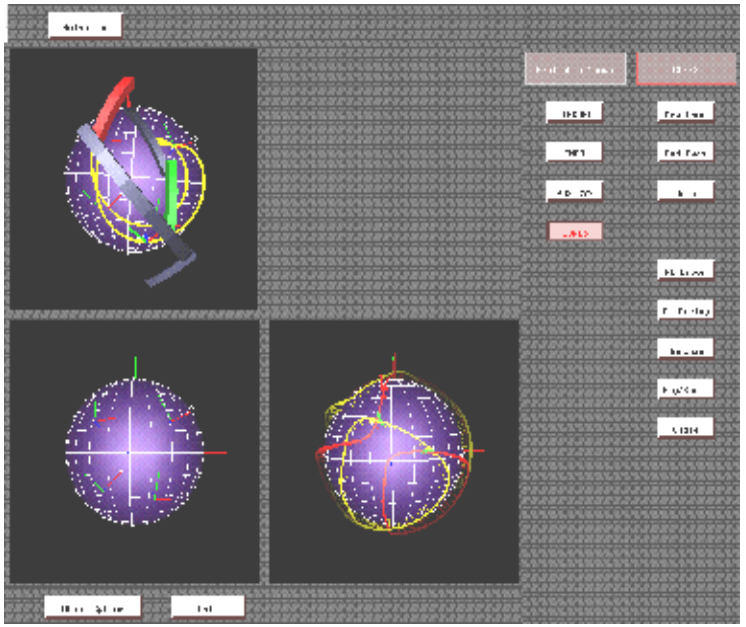




Kraal, Juliet C., and Vance, Judy M., "VEMECS: A virtual reality interface for spherical mechanism design," *Journal of Engineering Design*, 2001, 12(3), 245-354.



VEMECS

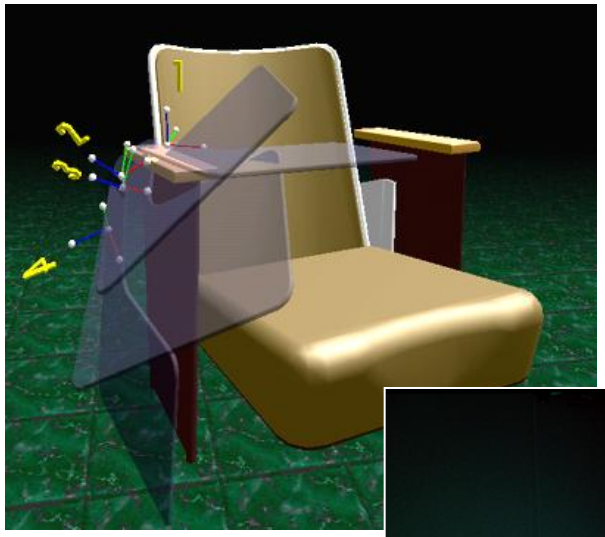


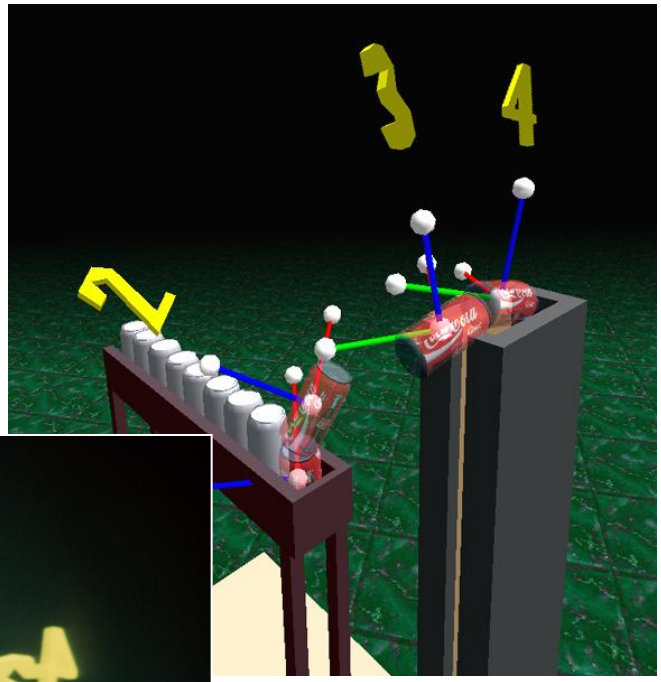
Sphinx

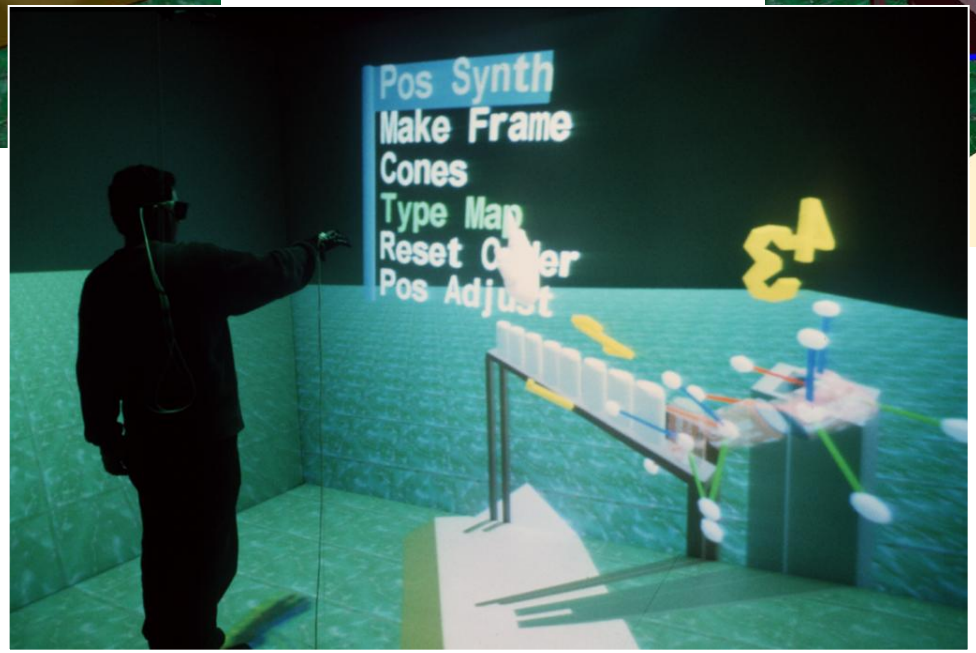
Larochelle, P., Dooley, J.,
Murray, A., & McCarthy, J. M. (1993)

Evans, Paul T., Vance, Judy M., and Dark, Veronica J., “Assessing the effectiveness of traditional and virtual reality interfaces in spherical mechanism design,” *ASME Journal of Mechanical Design*, 121(4), December 1999, pp.507-514.

Isis

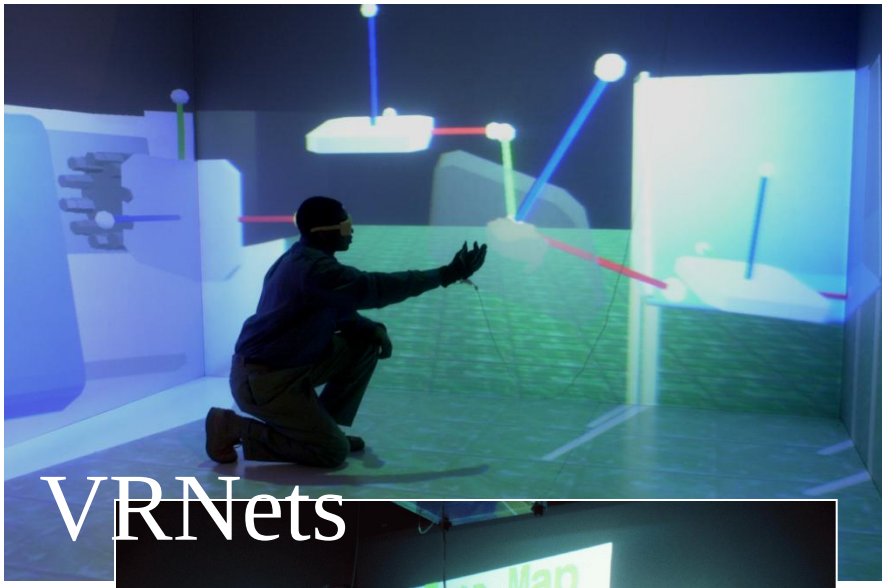


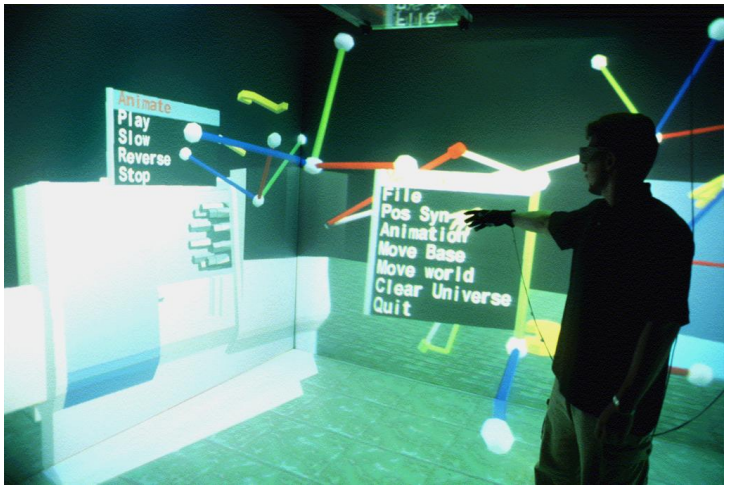


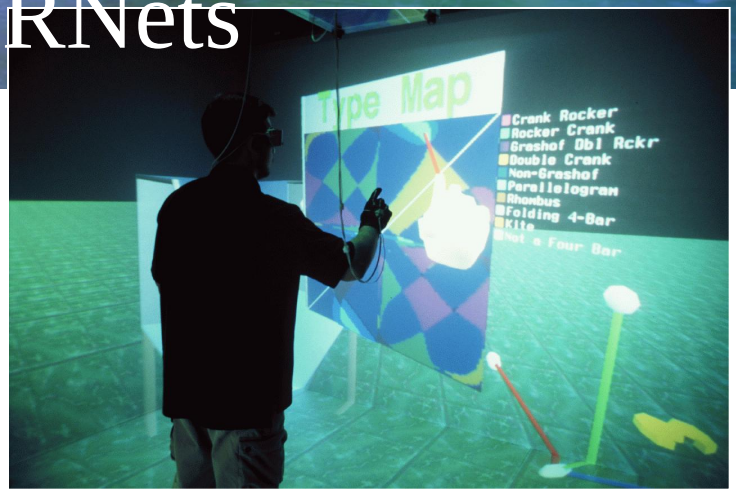


Furlong, Todd J., Vance, Judy M., and Larochelle, Pierre M., "Spherical mechanism synthesis in virtual reality," *ASME Journal of Mechanical Design*, 121(4), December 1999, pp. 515-520.

Spatial Mechanism Design

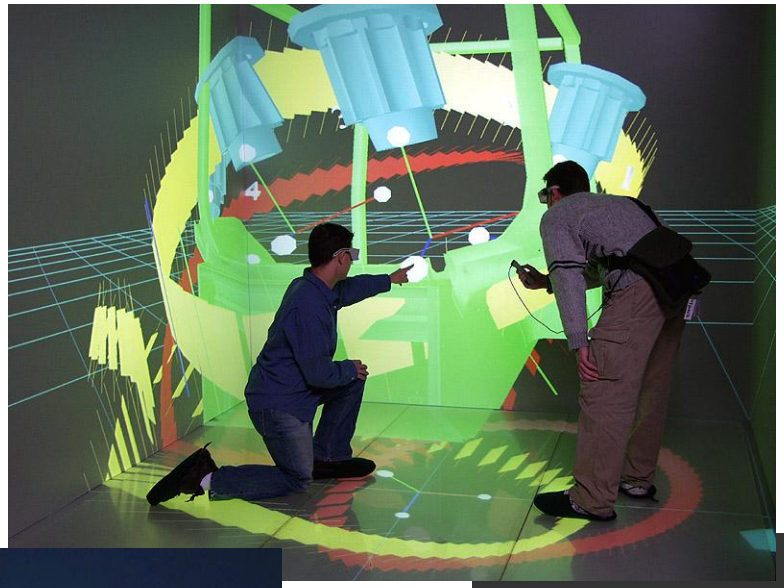


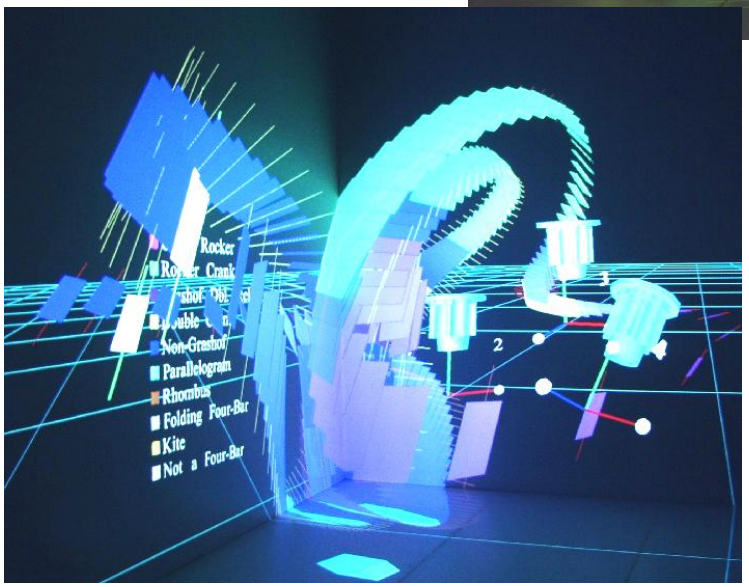


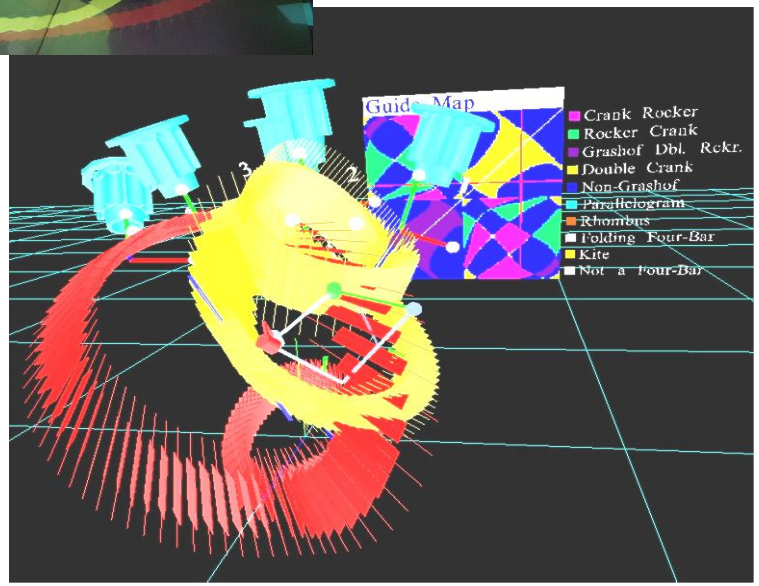


Kihonge, John N., Vance, Judy M., and Larochelle, Pierre M., "Spatial mechanism design in virtual reality with networking," *ASME Journal of Mechanical Design*, 124(3), September, 2002, pp. 435-440.

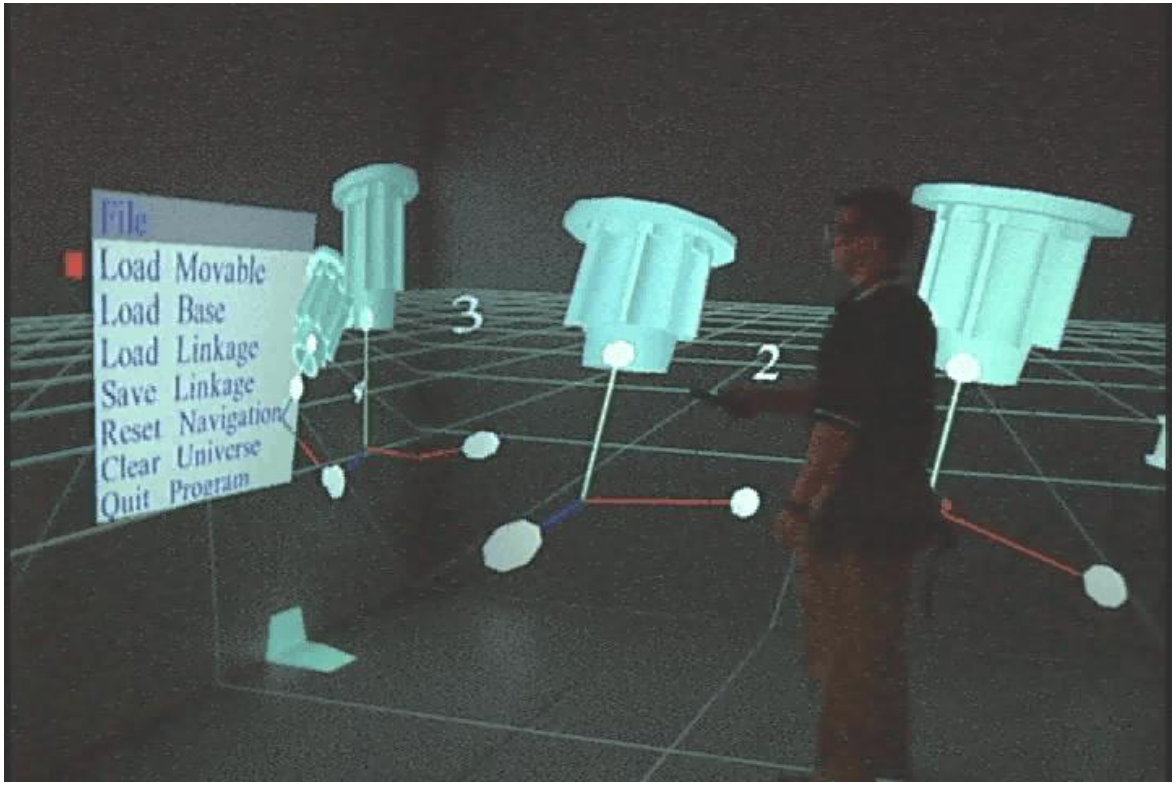
VRSpatial







Vance, Judy M., Larochelle, Pierre M., Dorozhkine, Denis, "VRSpatial: Designing spatial mechanisms using virtual reality," *ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Montreal, Canada, September 29-Octover 2, 2002, DETC2002/MECH-34377.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Conclusions

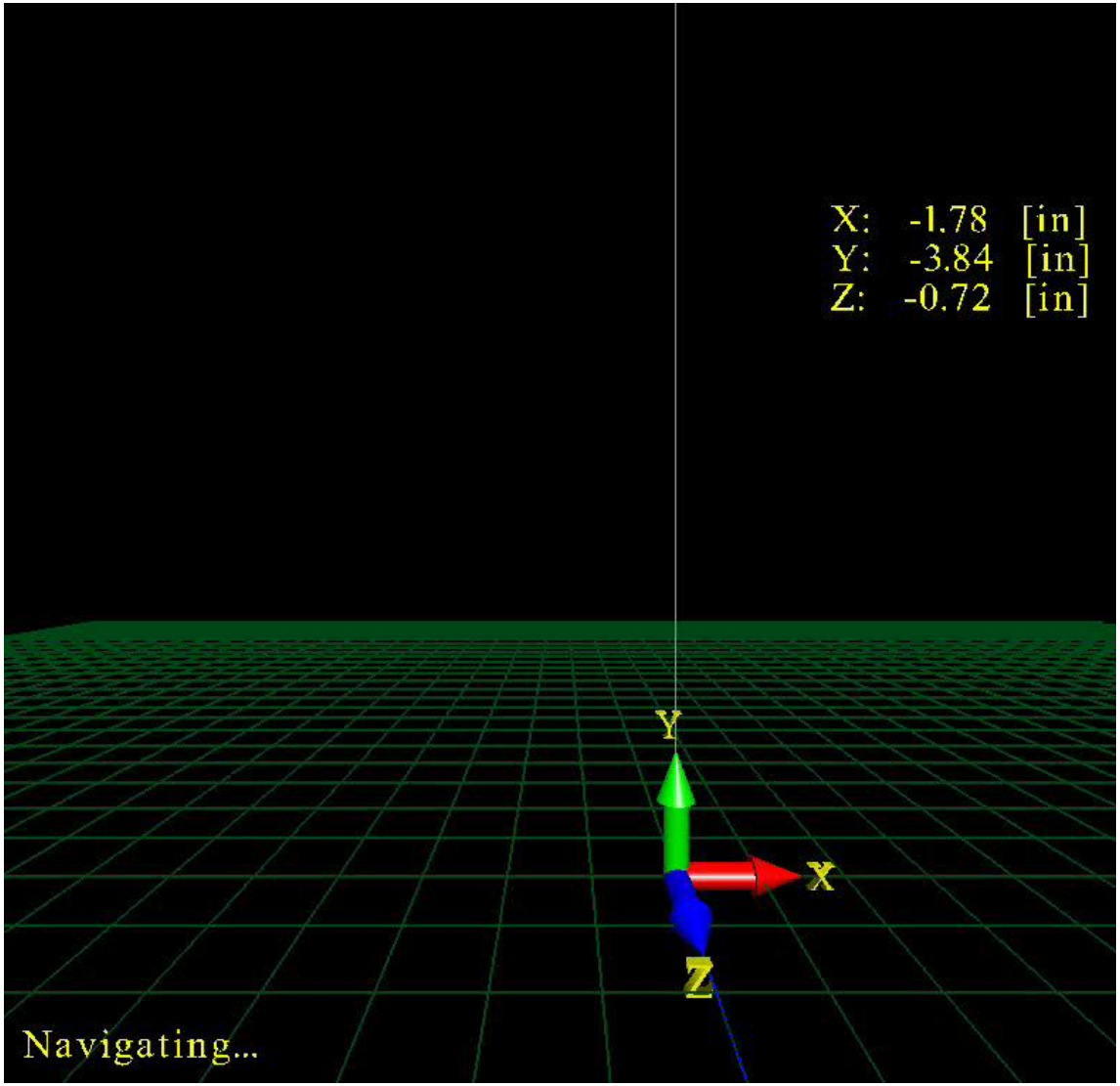
VRSpatial is a novel design tool that offers the mechanism designers a wide variety of methods for defining the initial design problem, solving the problem, and evaluating the solution's feasibility

Future work will continue to address how to effectively present the task solution space to the designers so that appropriate design decisions can be made in an effective manner

Compliant Mechanism Design Using Virtual Reality as a Design Interface

The purpose of this research is to establish an engineering framework for design of compliant mechanisms based on constraint-based compliant mechanism design theory and virtual reality.

Joint research with Dr. Martin Culpepper, MIT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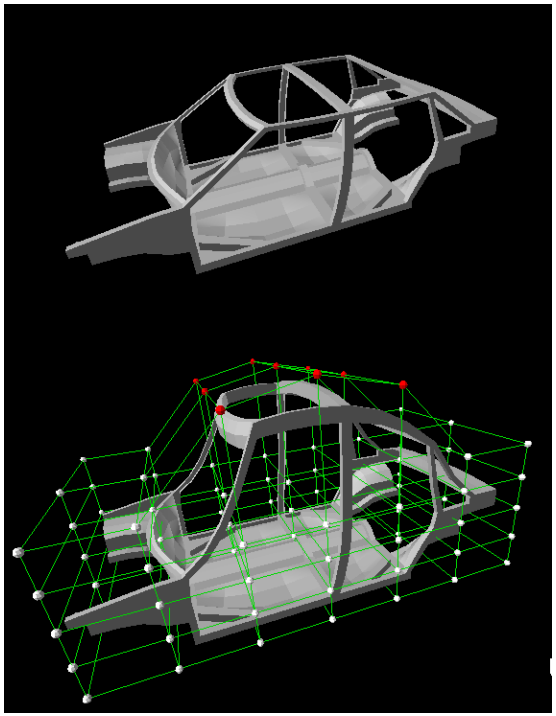
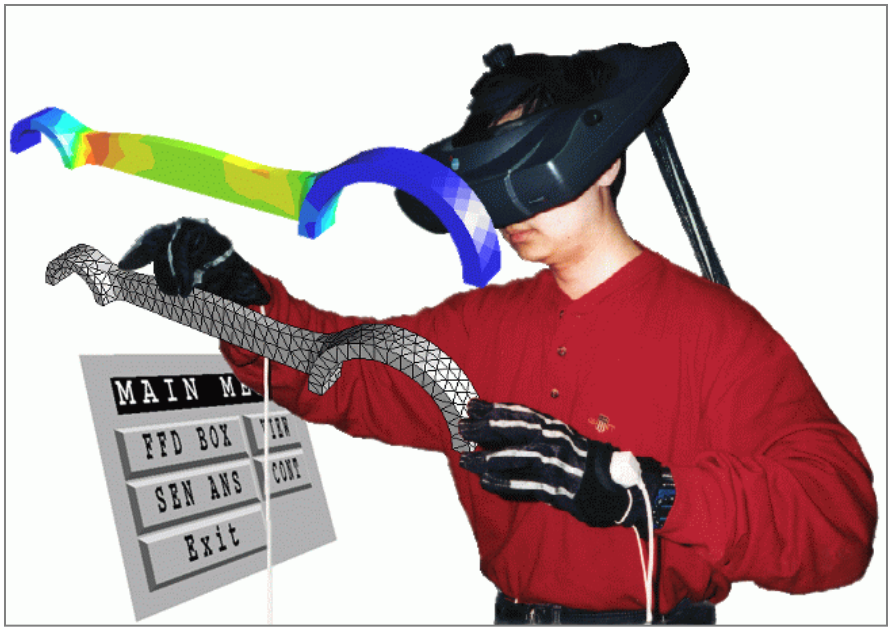
Interactive Stress Analysis

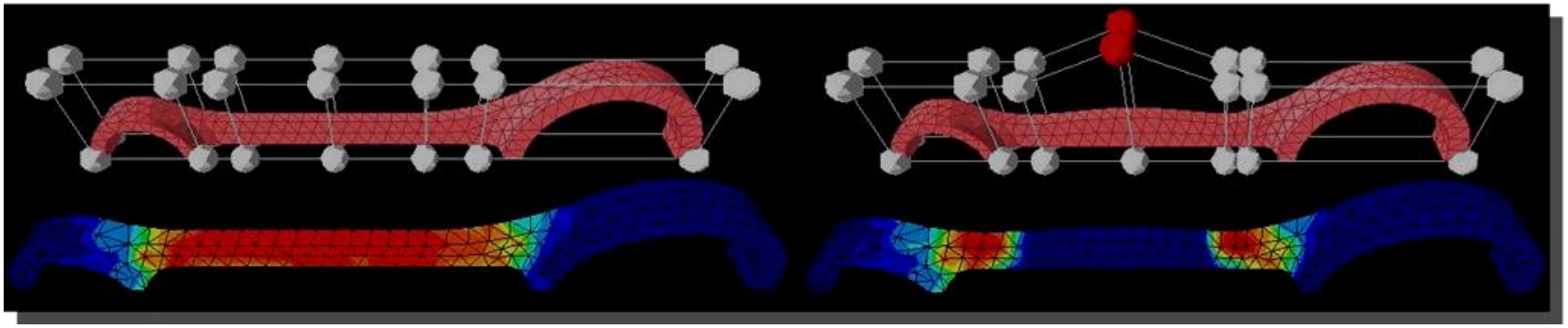
Provide interactive stress analysis and accurate approximations while changing part shapes in virtual reality with force feedback

Motivation

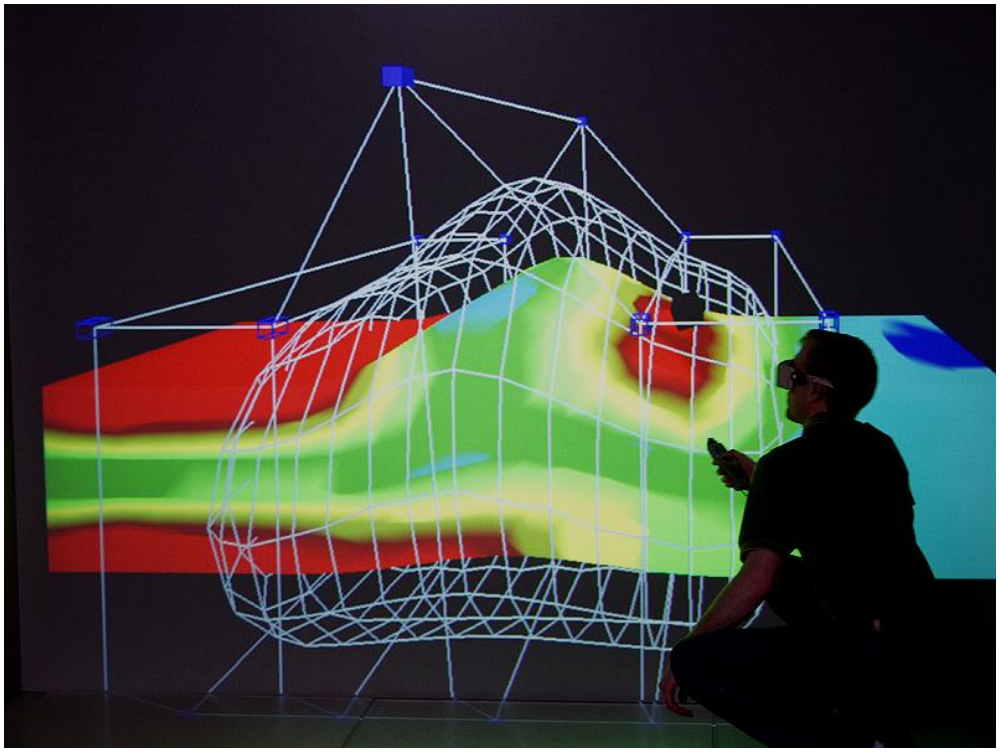
Providing a tool where one person can explore the design space by easily examining the effects shape changes have on stress distributions will reduce the design time for new products and allow designers to find unique solutions that might be missed using traditional shape optimization techniques.







Yeh, T.-P. and Vance, Judy M., "Applying virtual reality techniques to sensitivity-based structural shape design," *ASME Journal of Mechanical Design*, 120(4), December 1998, pp. 612-619.



Chipperfield, K., Vance, J. M., Fischer, A., “ Fast meshless reanalysis using combined approximations, pre-conditioned conjugate gradient, and Taylor series”, AIAA Journal, in press, 2006.

Methods

Stress Analysis

- Uses stabilized conforming nodal integration for the reproducing kernel meshless method
- Calculates displacement at any point in terms of nodal coefficients

$$u(x) = \sum_{i}^{N} \Psi_i(x) d_i$$

- Avoids re-meshing for deformations
- Use approximate solutions for speed

Fast Approximations

Linear Taylor Series

$$\sigma' = \sigma + s\Delta d$$

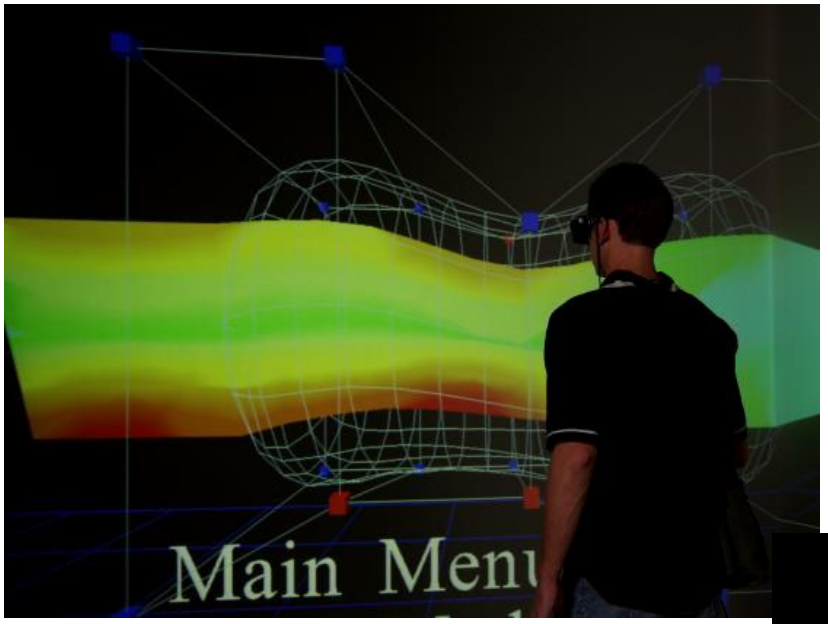
- Uses stress sensitivities
- Fast enough for real time
- Poor accuracy for large design changes

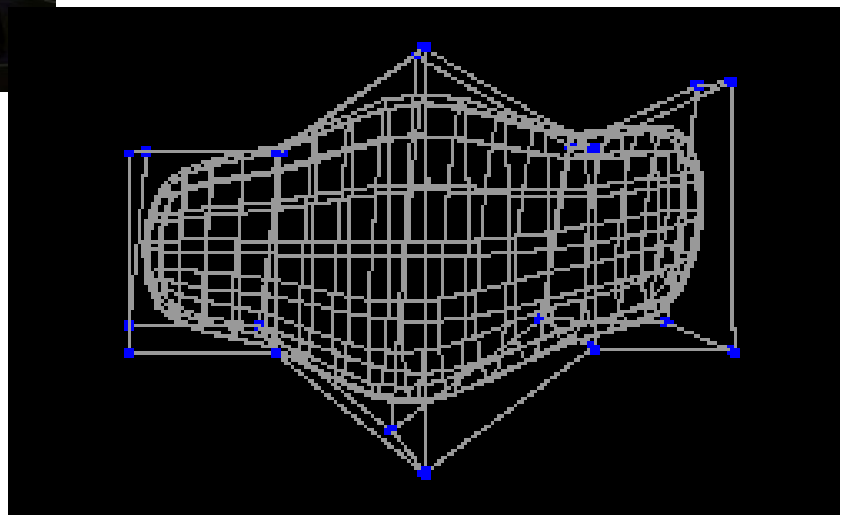
Pre-conditioned Conjugate Gradient method

$$K^* d^* = f^*$$

- Resolve system of equations
- Iterative technique is more accurate but slower
- Used at intervals to improve solution and compute new sensitivities

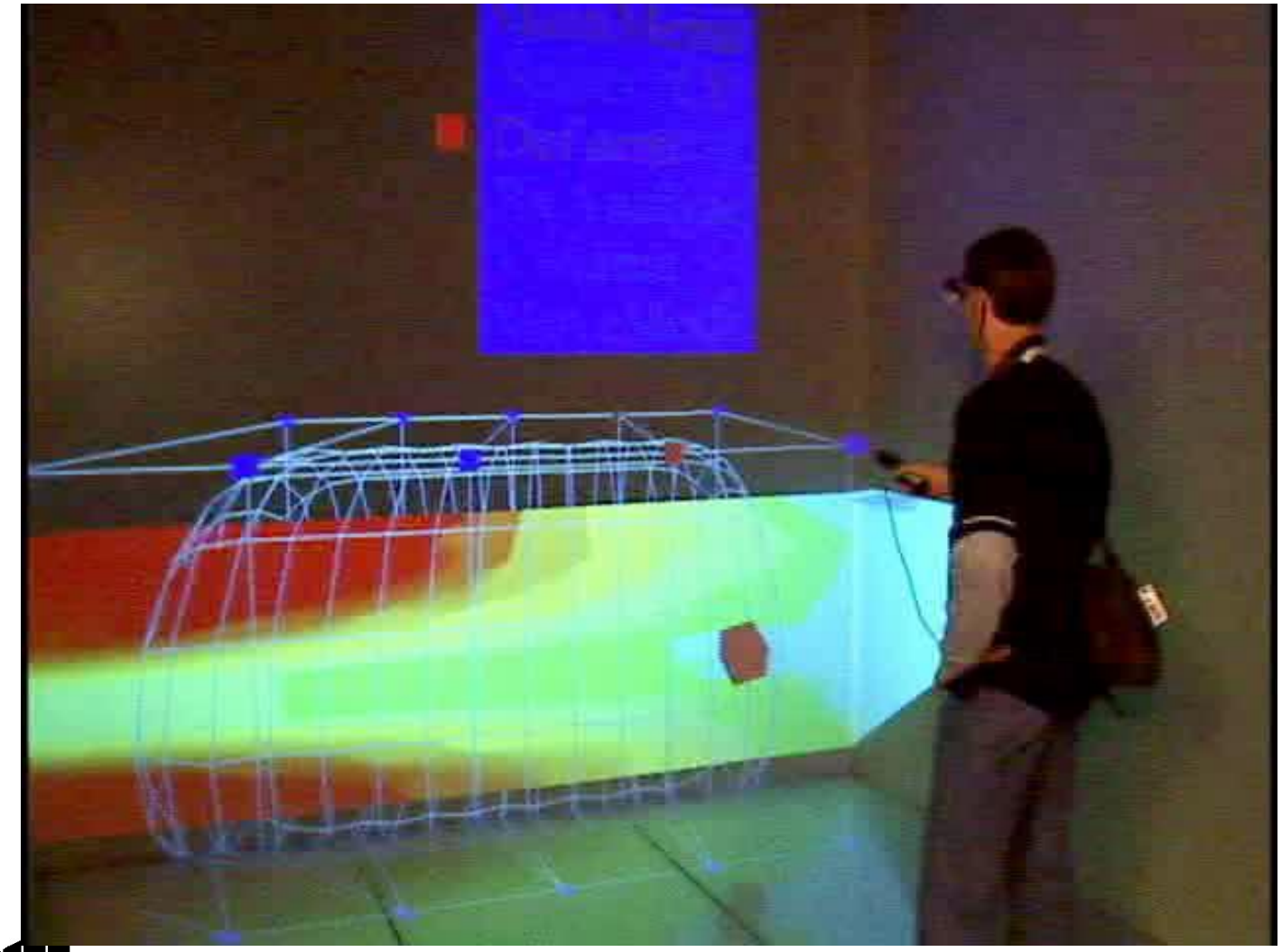
VrM3D





Catmull-Clark Subdivision method

Fischer, Andrew G. and Vance, Judy M. “An Overview of the VrM3D Virtual Design Program,” *2004 NSF Design, Service and Manufacturing Grantees and Research Conference Proceedings*, Dallas, TX, January 5-8, 2004



Conclusions

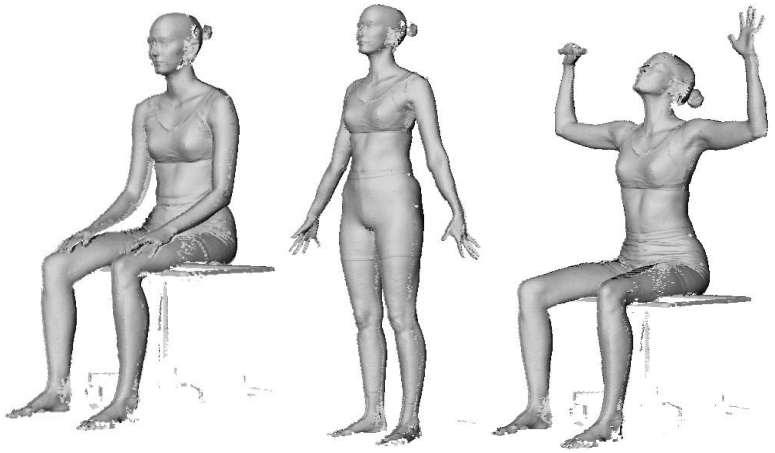
Fast finite element approximation methods combined with free form deformation allows the designer to quickly investigate shape change effects on stress distributions within a product.

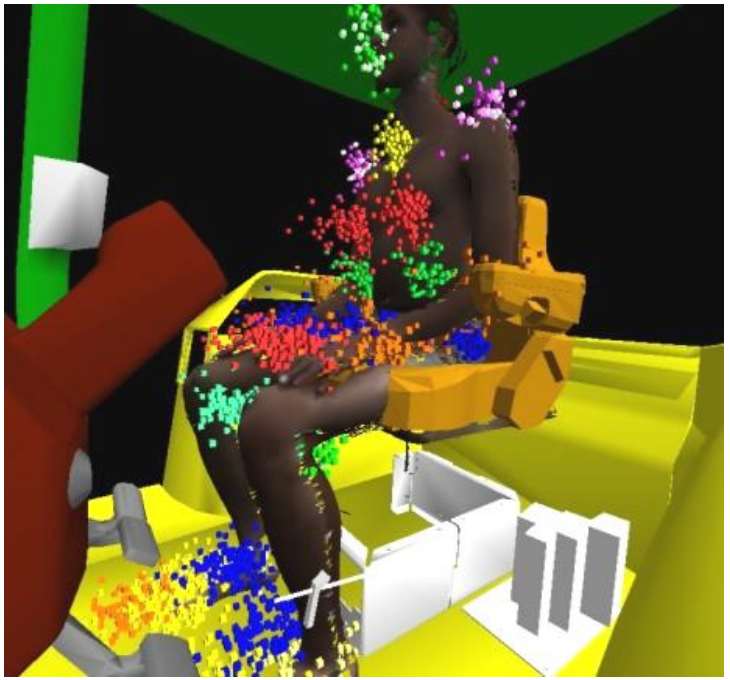
Future work will investigate the use of haptics as an additional information source and explore collision detection for assembly.

Ergonomic Design

Utilize three-dimensional anthropometric databases for improved ergonomic design of operator workstations

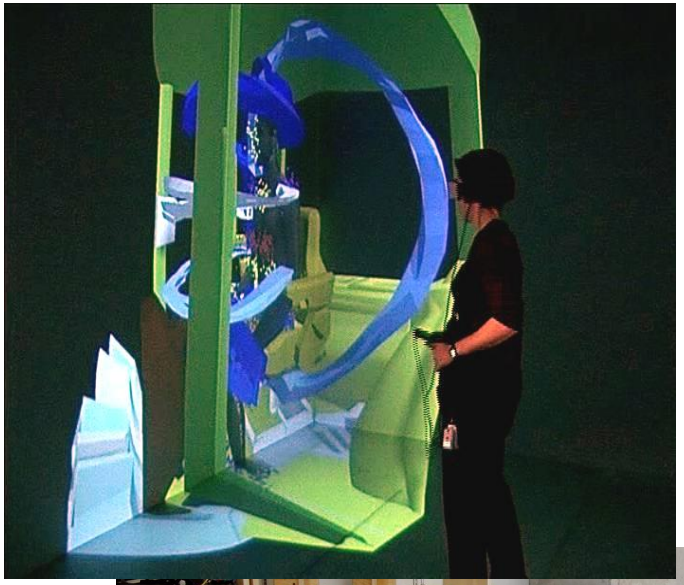
Methods

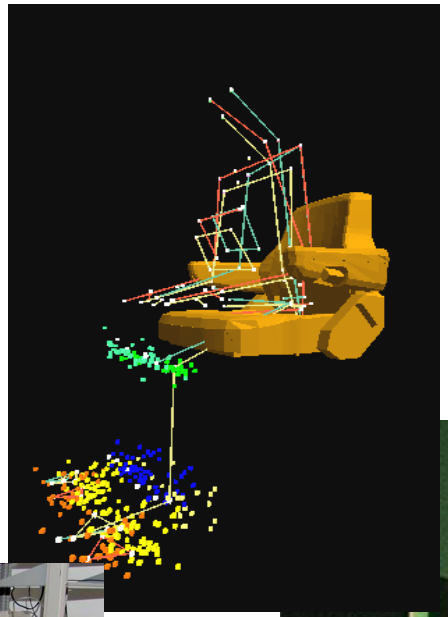


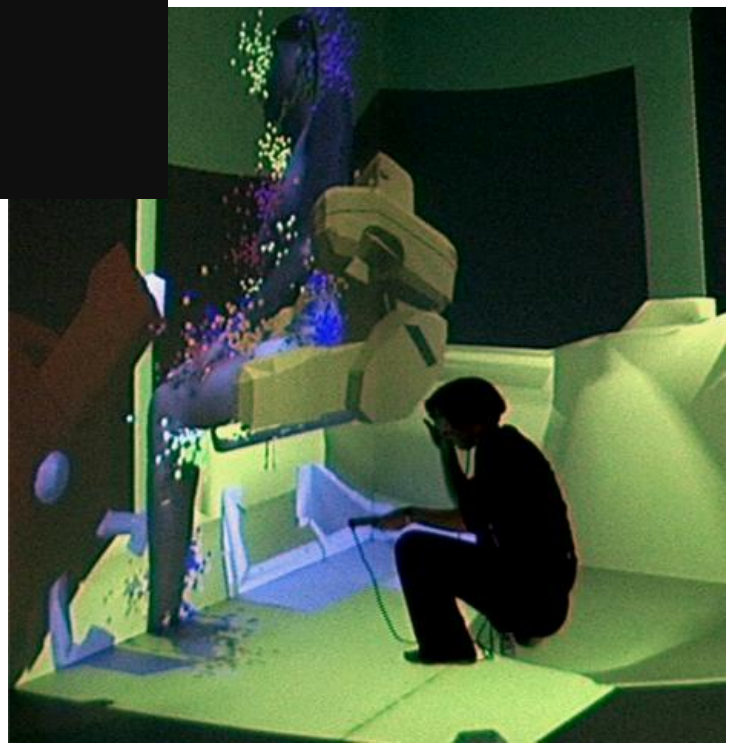


3-D anthropometric data

- CAESAR and proprietary databases
- Landmarks, body scans and other custom data types
- Rich set of demographic data available for each subject







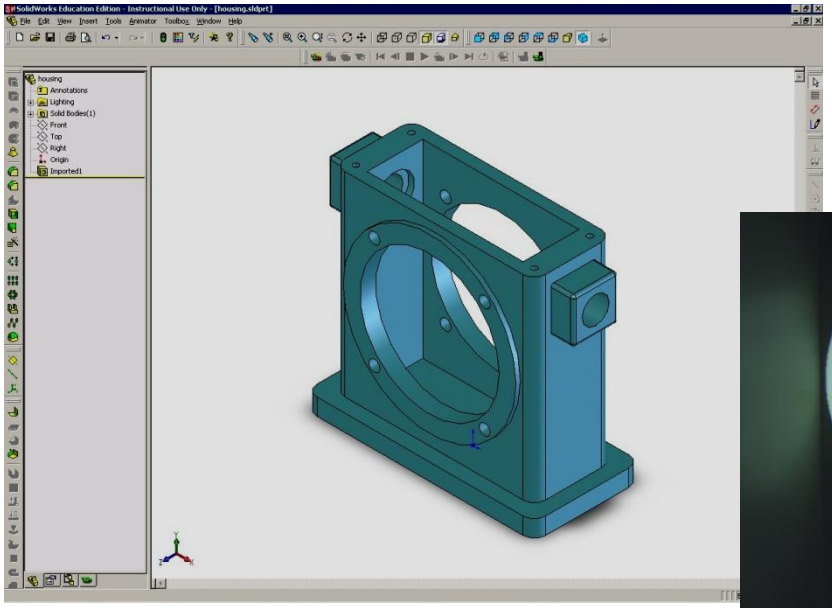
Cerney, M. M., Duncan, J.R., Vance, J.M., "Using Population Data and Immersive Virtual Reality for Ergonomic Design of Operator Workstations," *SAE Digital Human Modeling Conference Proceedings*, Munich, Germany, June 18-20, 2002.

VR Assembly

Explore the use of virtual reality as a tool to aid in the evaluation of product designs for assembly

- Assembly methods prototyping
- Discrete event simulation

VR Assembly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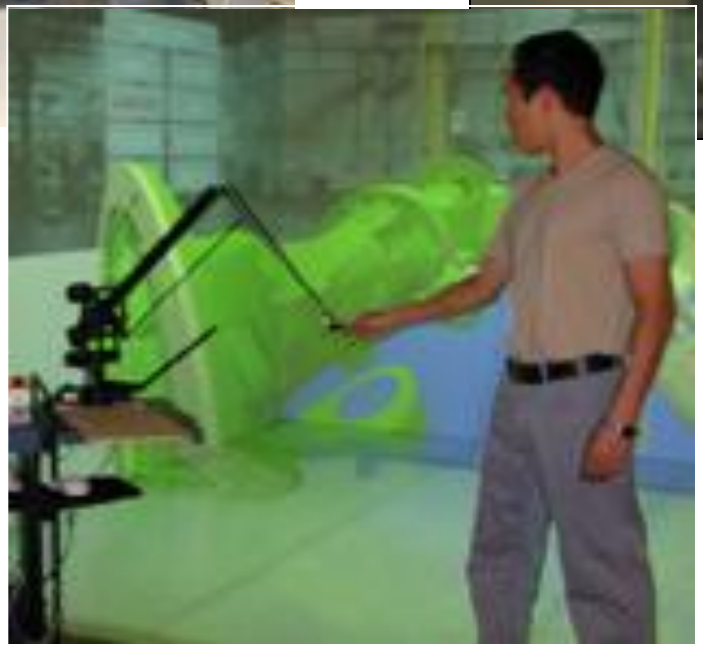
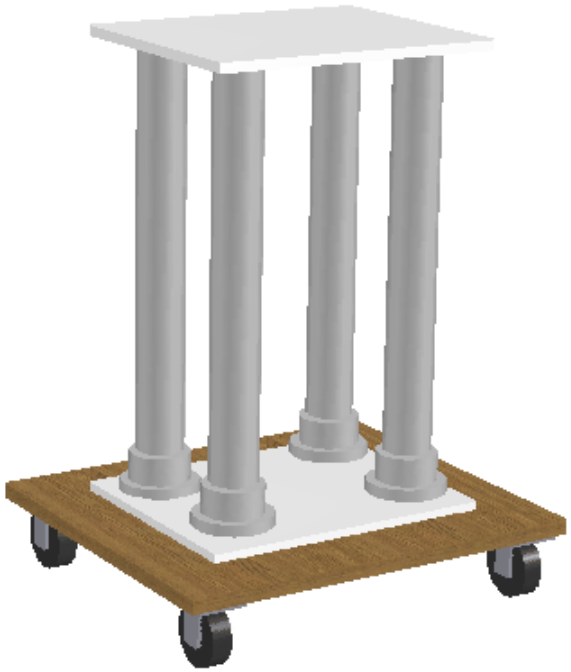
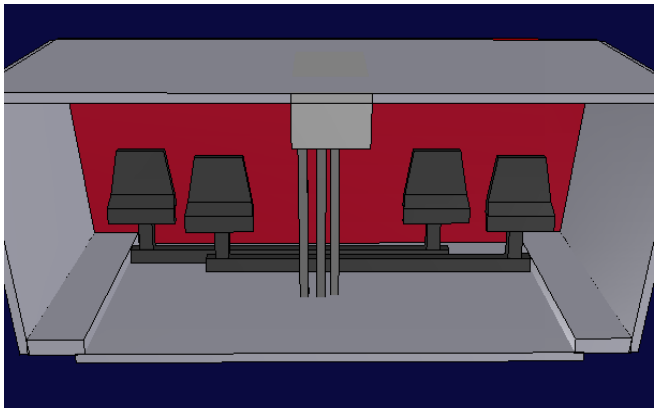


Networked Haptic Environment

Kim, ChangEun, Vance, J.M., "Development of a networked haptic environment in VR to facilitate collaborative design using Voxmap Pointshell (VPS) software," *ASME Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Salt Lake City, Utah, September 28 to October 2, 2004, DETC2004/CIE-57648.



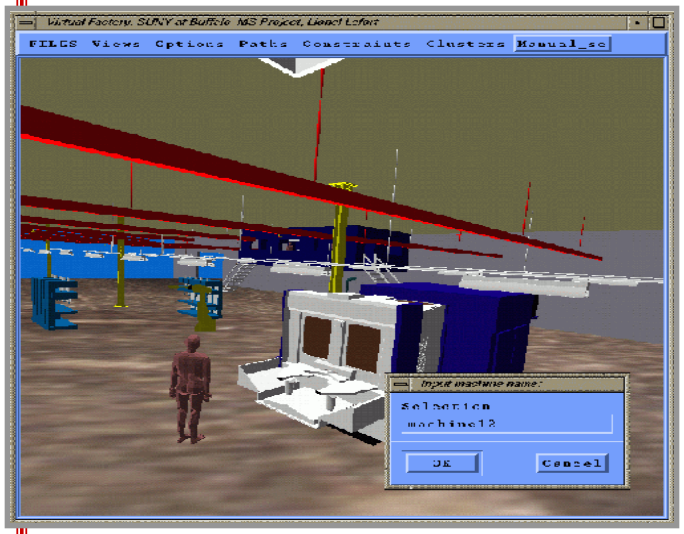


Fischer, A. G., Vance, J. M., "PHANToM Haptic Device Implemented in a Projection Screen Virtual Environment," *IPT/EGVE 2003 Workshop Proceedings*, Zurich, Switzerland, May 22-23, 2003.

Discrete Event Simulation in VR

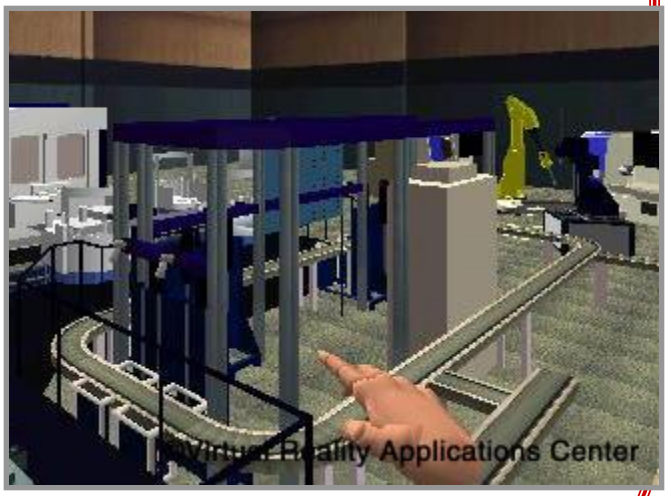
To develop a Virtual Reality training environment and laboratory for production assemblers with the aid of concurrent operations simulation

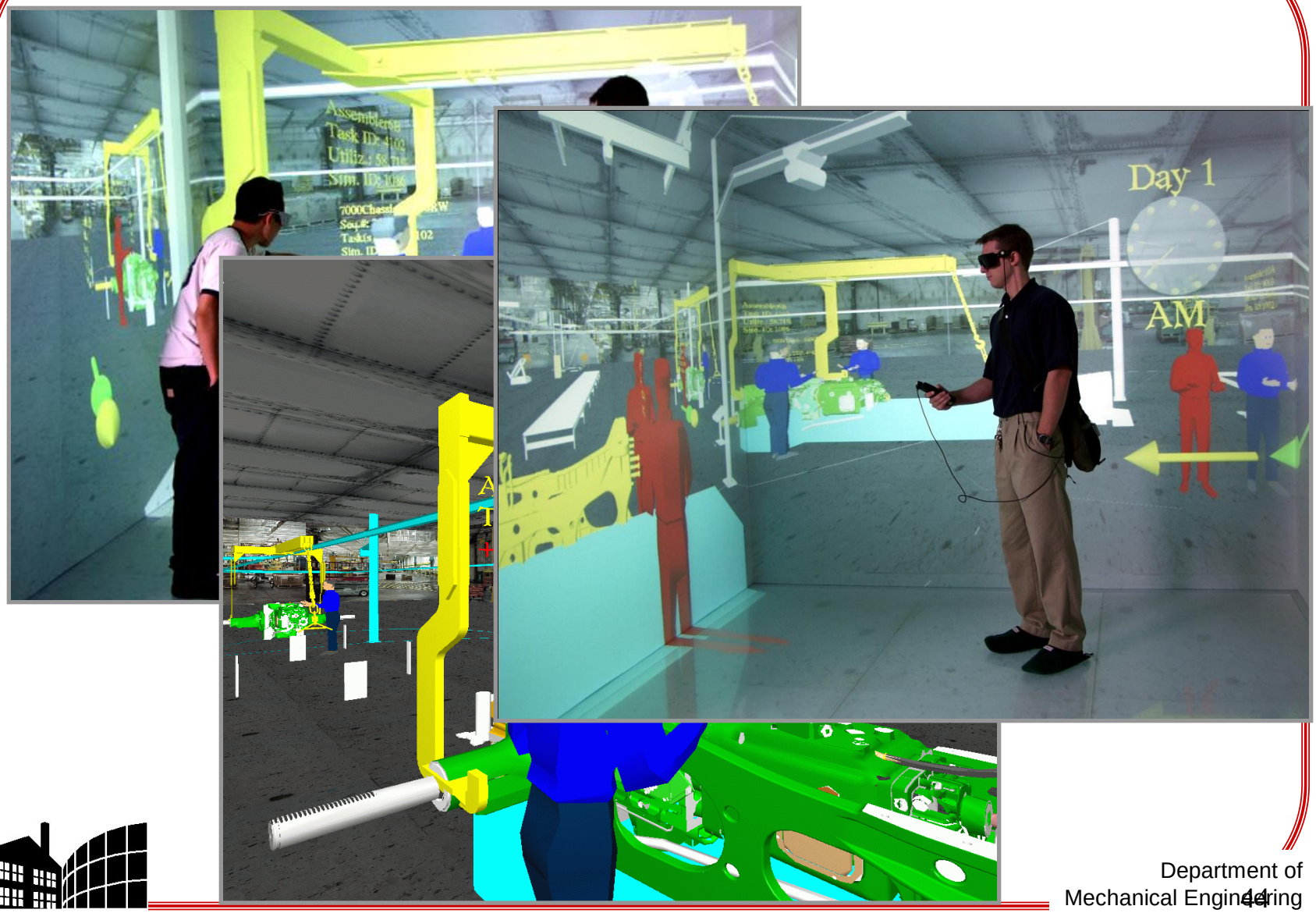
Current state of VR simulation



VR-Fact – virtual environment for modeling and designing factories and shop floors (Kesavadas and Ernzner, University of Buffalo).

VRFactory – an interface to a commercial discrete event simulation software (SLAM II) (Vance and Kelsick, Iowa State University).

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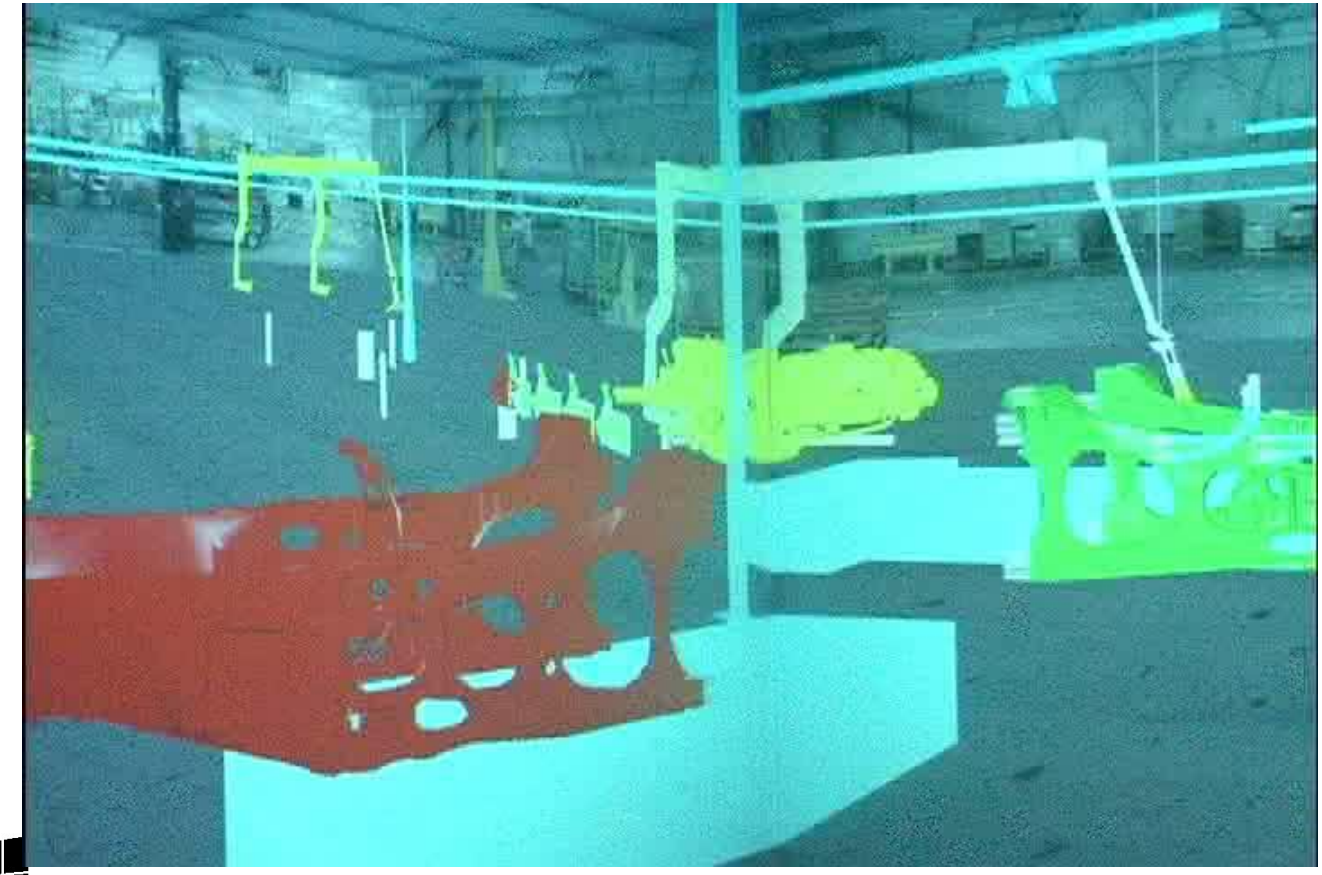
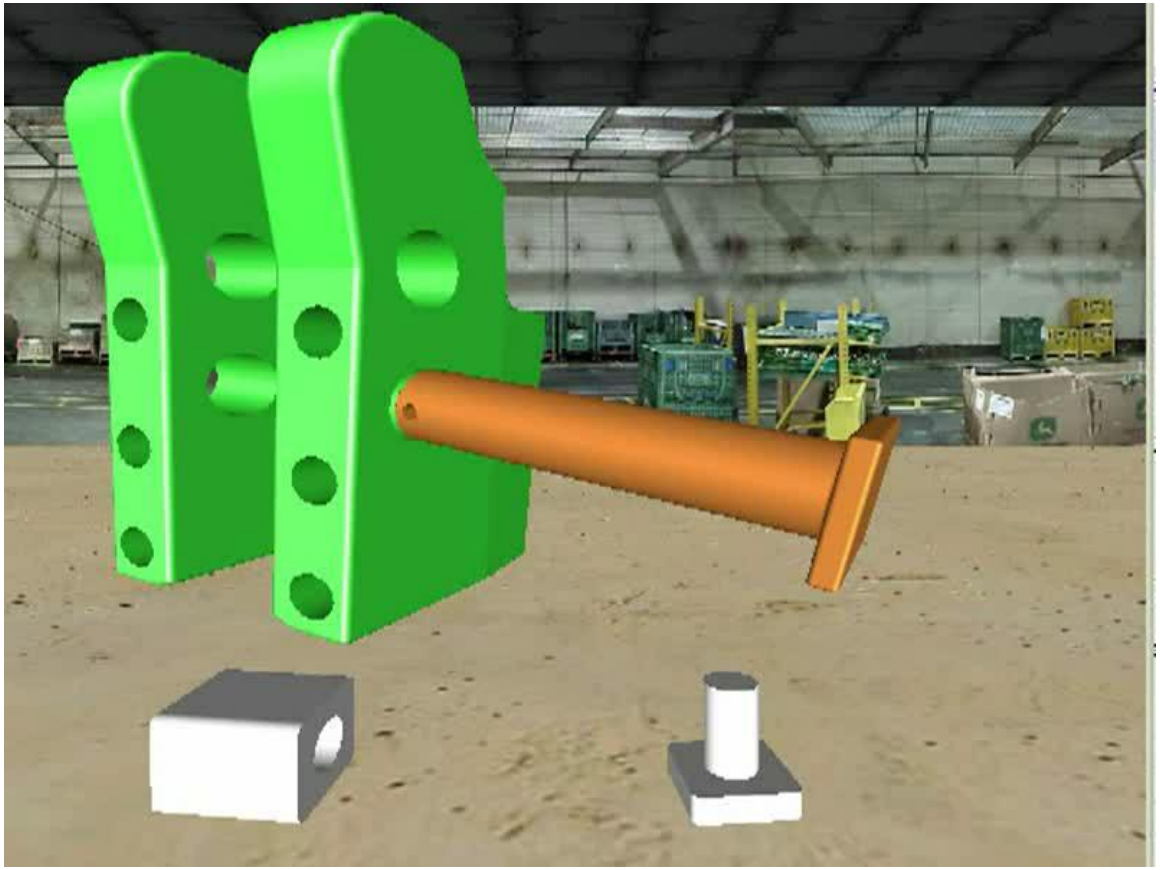



Card Stack UI



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