INTERACTIVE MESH-FREE STRESS ANALYSIS FOR MECHANICAL DESIGN ASSEMBLY WITH HAPTICS

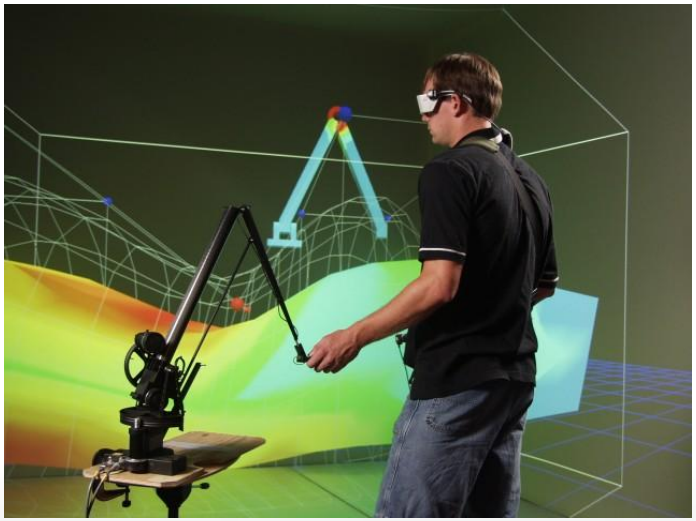
International Design Engineering Conference, 2007

Daniela Faas, **Dr**. **Andrew Fischer and Dr. Judy M. Vance***

Department of Mechanical Engineering, Virtual Reality Applications Center,
Iowa State University
*Program Director for Engineering Design
Civil, Mechanical, and Manufacturing Innovation Division
National Science Foundation

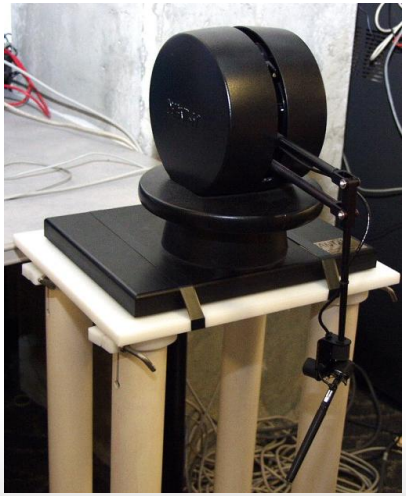
Why Design in VR?

- Time & cost savings.
- Easier identification of problematic stresses in the design.
- Faster product development.
- Collaborative Design.



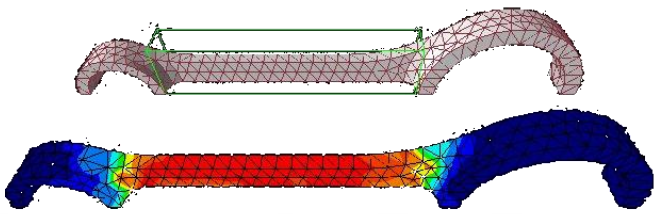
Virtual Reality Environment

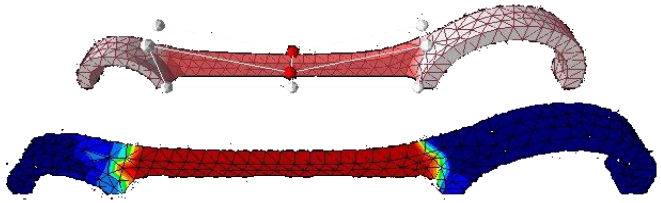
- Developed for C4 and C6 at VRAC, Iowa State.
- Renovated C6:
  - 4000x4000 pixel resolution per wall.
  - 48 dual-CPU workstations.
  - 24 Sony SRX-S105 digital cinema projectors.
- Phantom Haptic Device



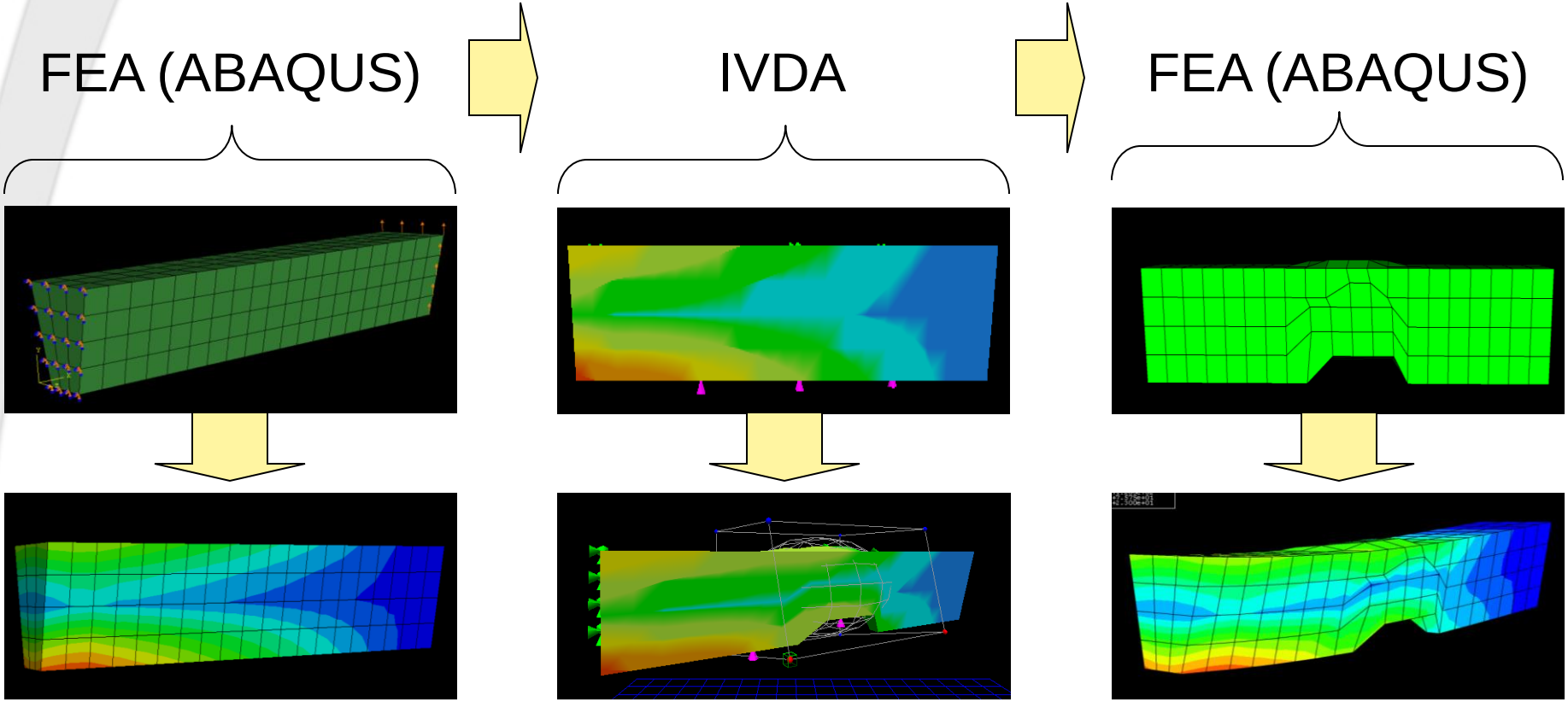
IVDA: Background

- Yeh and Vance, 1998: linear Taylor series approximations based on pre-computed stress sensitivities and NURBS bounding volume to deform part shape.
- Chipperfield et al., 2006 : PCG re-analysis method to accurately re-compute stress.
- Mesh-free solver to allow for larger design changes





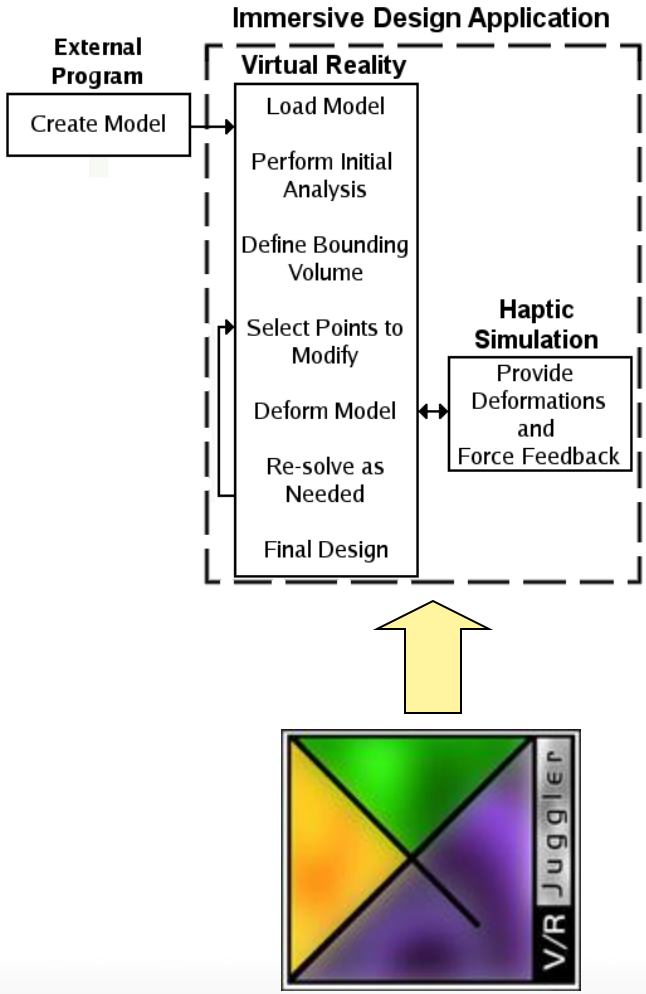
IVDA Design Process



- Optimized design through less iterations

IVDA: Software Used

- C++ programming language.
- VR Juggler software toolkit.
- OpenGl.
- OpenHaptics toolkit for Phantom haptic device.
- OPCODE (Optimized Collision detection).



Mesh-free analysis

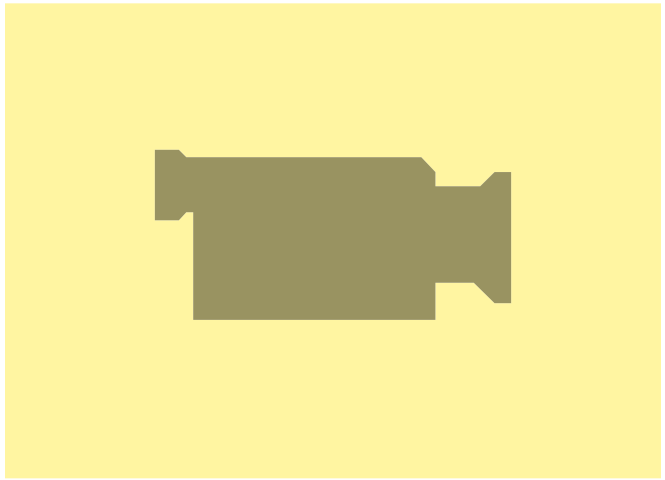
- Tahoe OpenSource toolkit (http://tahoe.ca.sandia.gov/).
- 2D and 3D elements, several material models.
- Reproducing kernel particle method (RKPM):

$$u^h(\mathbf{x}) = \sum_{I=1}^{N} \Psi_I(\mathbf{x}) \; d_I \qquad \boldsymbol{\varepsilon}^h(\mathbf{x}_L) = \sum_{I \in G_L} \mathbf{B}_I(\mathbf{x}_L)\mathbf{d}_I$$

- $u^h(x)$ = displacement.
- $\Psi_L(x)$ =reproducing kernel shape function.
- d_L = vector of displacement coefficients.
- (x_L) = strain at node *L.*
- $\mathbf{B}_I$ = smoothed strain gradient matrix.

Model Deformation / PCG Reanalysis

Assembly Operations



Conclusion

- Able to perform mesh-free analysis.
- Able to deform model with stress updates.
- Able to assemble parts during deformation.
- During assembly operations, deformation cannot cause parts to intersect.
  - Limitation: 10% tolerance for fits.
- Optimization of shape through interactive design coupled with mesh-free analysis.

Acknowledgements

- Andrew Fischer.
- Funded by Proctor and Gamble.
- Virtual Reality Applications Center.
- Iowa State University.

Questions?