Virtual Reality
as a Human Computer Interface
to Mechanical Design

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Iowa State University

Ames, IA

Presentation Outline

- Virtual Reality Applications Center

- Implementing a Haptic Interface in a Projection System Environment

- Virtual Hydraulic Hose Routing

- Ergonomic Design using 3D Human Anthropometric Data

Virtual Reality Applications Center

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

34 Faculty
from 16 Departments and 4 Colleges

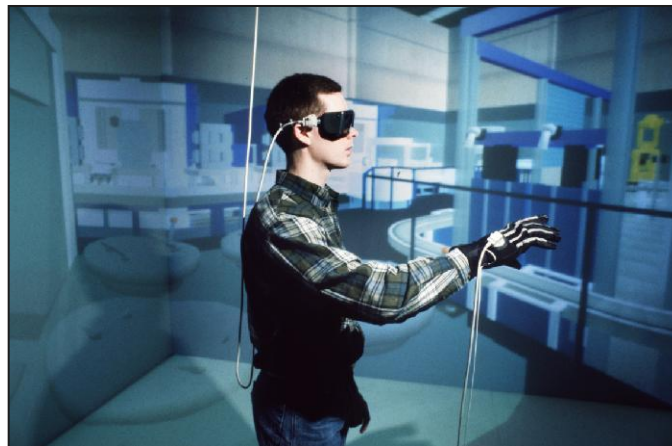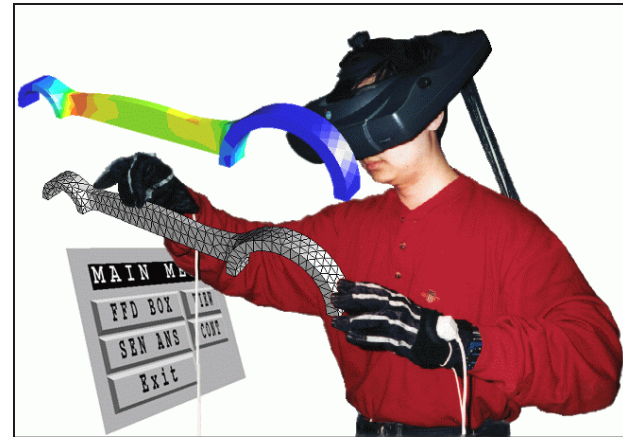76 Graduate Students
59 Undergraduate Students

Facilities

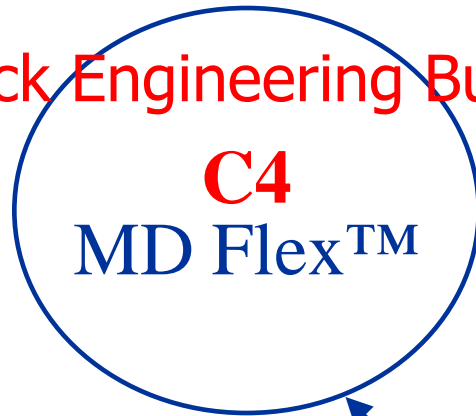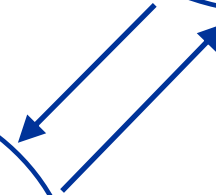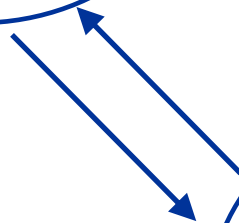20,000 sg. ft. laboratory/office complex in
Howe Hall
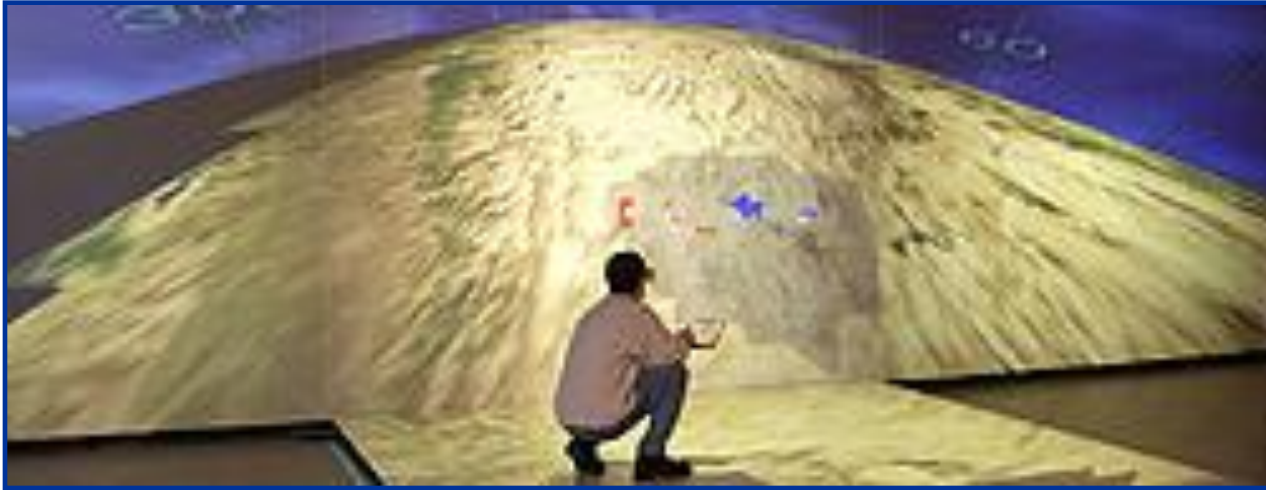
Facilities

Immersive Projection Facilities

Black Engineering Building

C4
MD Flex™

Howe Hall

C6
6 wall

Lee Liu
Auditorium

Howe Hall

C4: MD Flex™

- 12' x 12' x 9' facility
- 3 walls and floor stereo projection
- Outer walls can fold out to provide a 36' x 9' viewing surface
- SGI ONYX with 3 - Infinite Reality graphics pipes and 16 - R10000 processors
- Nuvision and StereoGraphics active stereo glasses
- Ascension Technology Wireless MotionStar tracking system
- Barco projectors

The C6

Entire facility is 3 stories high

Occupies the atrium of Howe Hall

C6: 6 walls, wireless tracking

- 10' x 10' x 10' facility
- 4 walls, floor, and ceiling stereo projection
- Surround sound audio system
- SGI ONYX2 Reality Monster
  - 6 - Infinite Reality2 graphic pipes
  - 24 - R12000 processors @ 400 MHz
  - 256MB texture memory, 12Gb RAM

- Nuvision and StereoGraphics active stereo glasses
- Ascension Technology Wireless MotionStar tracking system
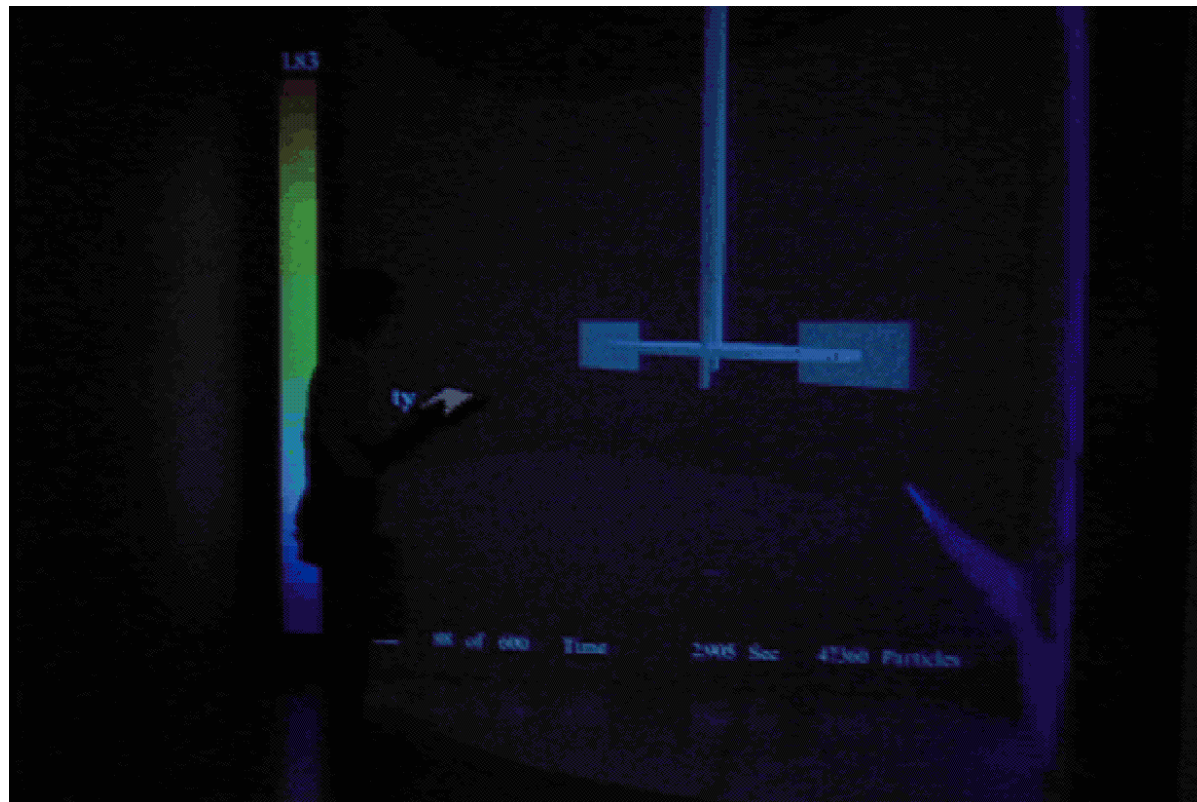- Barco Projectors
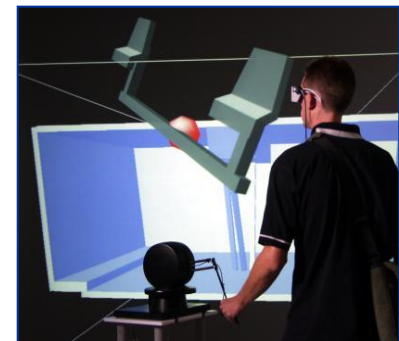
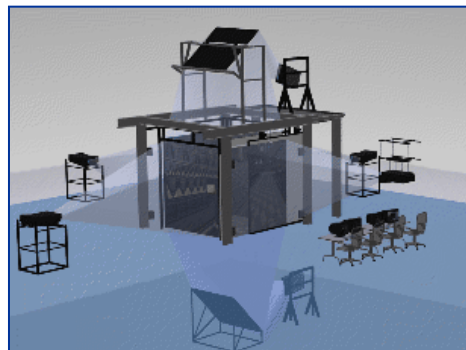# Movies

Spatial Mechanism Design
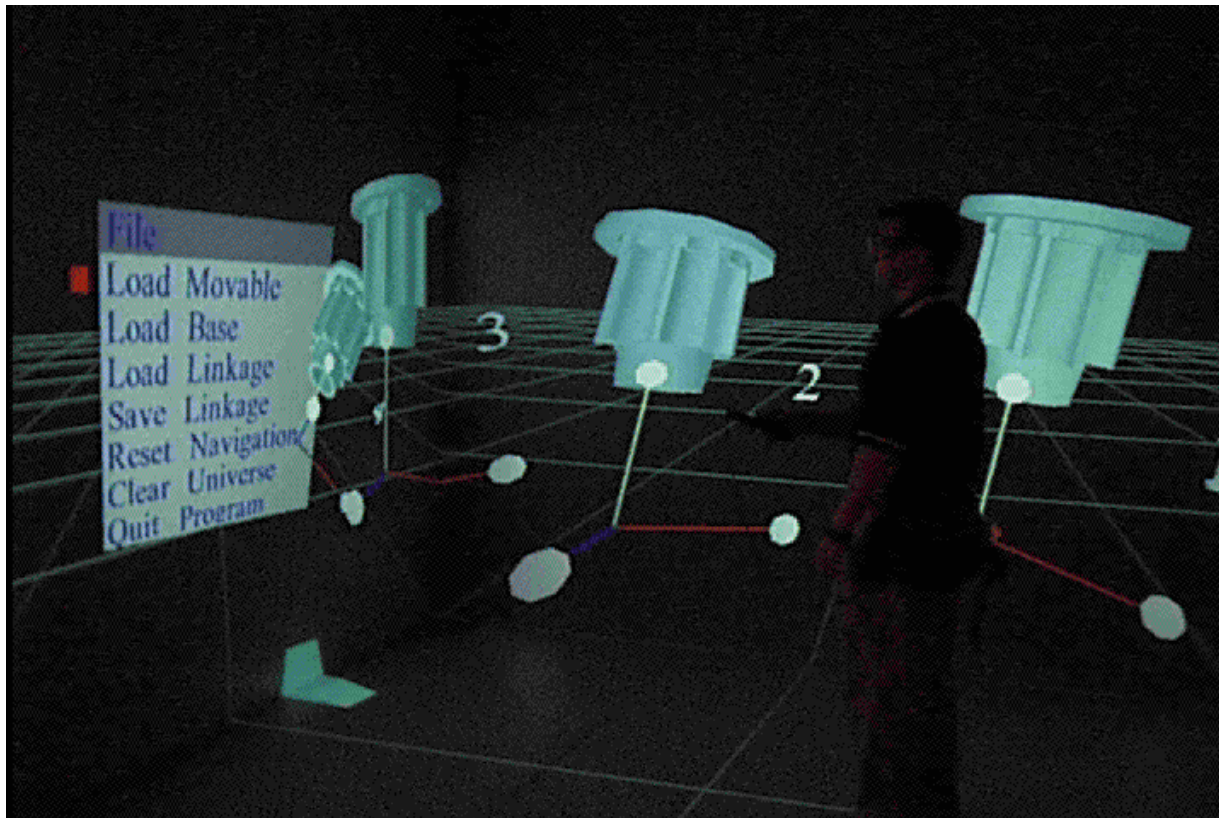
Movies

CFD Particle Tracing During Mixing

Implementing a Haptic Interface in a Projection System Environment

GOAL: To combine the PHANToM haptic device with a projection screen virtual environment and explore the benefits haptic devices bring to this type of immersive environment.
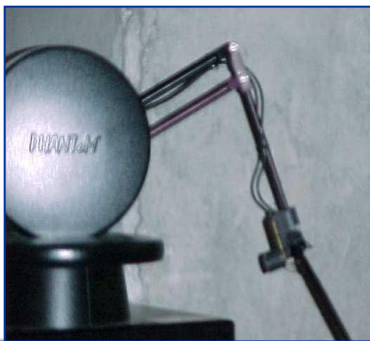
Motivation

Virtual Assembly

Interactive Shape Design

Haptic Device

Phantom 1.5

- Most common haptic device
- Generally used on the desktop

Challenges

- Mobility
- Scaling
- Occlusion
- Tracker interference

Implementation

- PHANToM Stand
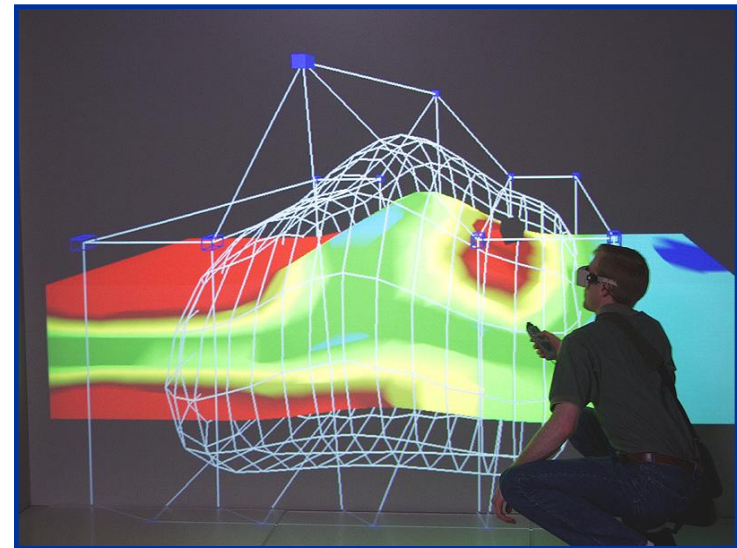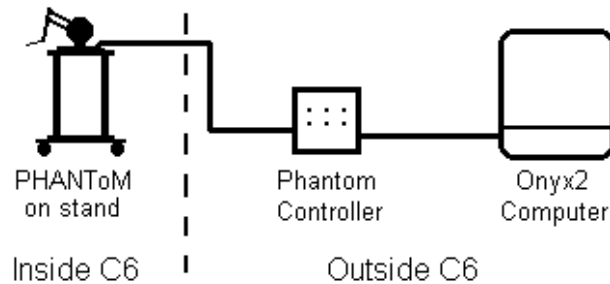
- PHANToM Volume
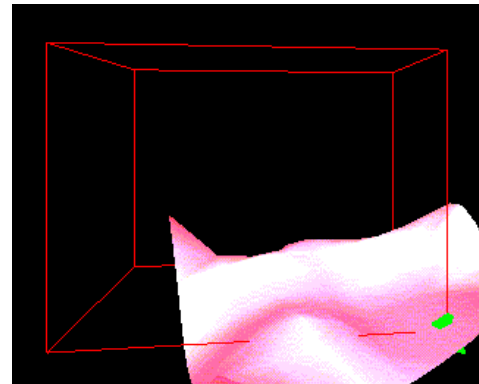
- PHANToM Driver

```
14
15 void PhantomDriver::StartPhantom(vjMatrix Tr
16     // SETUP SECTION
17     // If geometry isn't setup, exit
18     if(geometry_created!=1){
19     cerr << "Haptic Geometry Not Created "
20     exit(-1);
21     }
22
23     // Set the Center of the Phantom Volume
```

PHANToM Stand

- Movable

- Height adjustable

- Non-magnetic
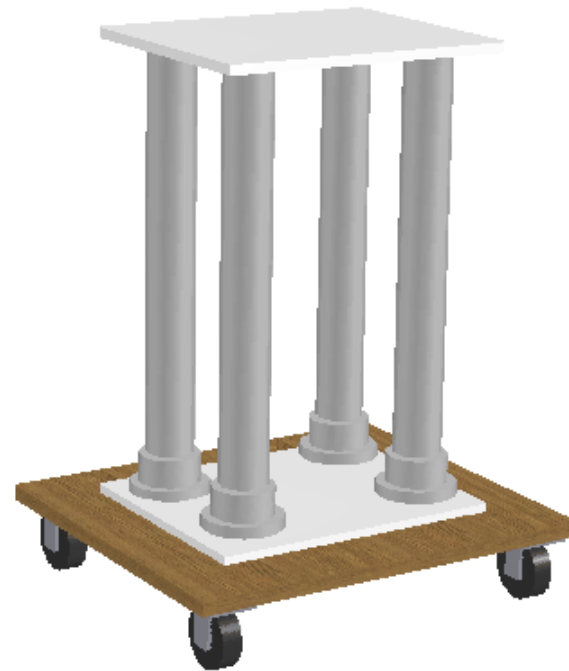
Phantom Volume

Create a 3D volume in the virtual environment that encompasses the part of the geometry that will be haptically enabled.

Map the workspace extents of the haptic device to be constrained to this defined volume.

Phantom Volume

Device Workspace

Virtual Workspace
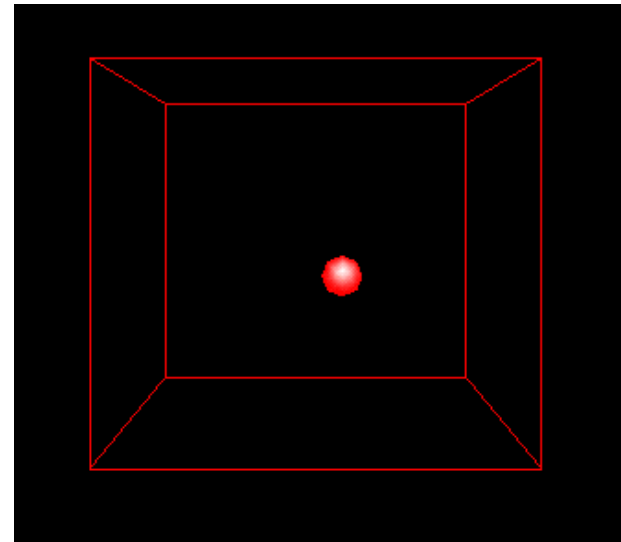
Phantom Volume

Workspace Scaling

- Maintain aspect ratio
- Use a single scale value
- Constrain the physical workspace of the PHANToM

$$a = world\_haptic\_scale = \frac{max\_device\_workspace\_dimension}{max\_virtual\_volume\_dimension}$$
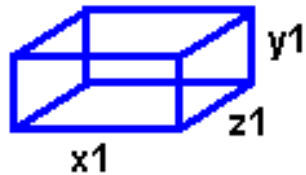
x1 = a x2
y1 = a y2
z1 = a z2
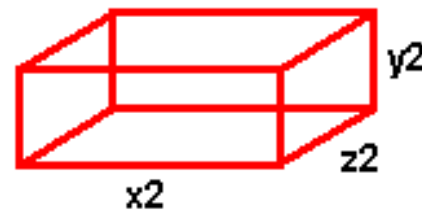
Device workspace

Virtual volume

PHANToM Driver

- Controls PHANToM through GHOST

- Haptic scene graph

- Positions PHANToM in virtual space

- Interacts with VrJuggler

PhantomDriver Haptic Scene Graph Structure

Scene
gstScene

Root Node
gstSeparator

HapticScene
gstSeparator

PhantomParent
gstSeparator

Haptic Geometry

ForceField
gstForceField

Phantom
gstPHANToM

Workspace
gstBoundaryCube
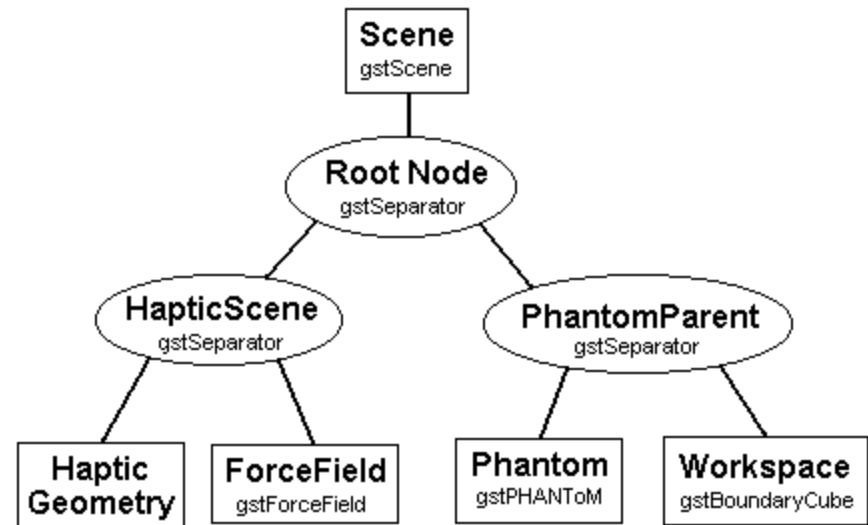
PHANToM Driver

Handles haptic process

Program Process

PhantomDriver Setup

Main Application

30Hz

Update Haptics

Quit Haptics

Haptic Process

1000Hz

Haptic Servo Loop

Haptic Servo Loop

Endpoint Position

Update Models

Detect Collisions

Calculate Forces

Return Forces
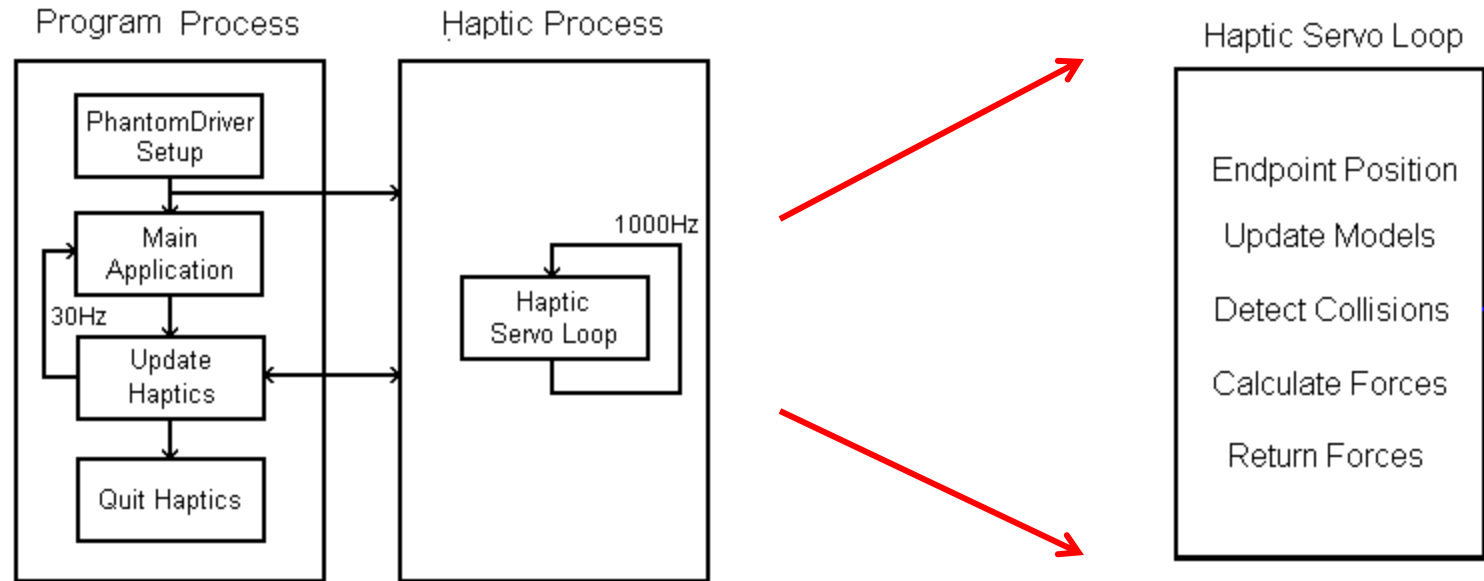
Two Example Programs

NURBS Surface

- Feel a surface
- Use GHOST defined haptic geometry

Rudder Pedal Installation

- Part manipulation with haptics
- Use VPS to determine collision forces

NURBS Surface Example

- NURBS surface created
- Polygonal Approximation
- GHOST TriPolyMesh Object
- Phantom Volume
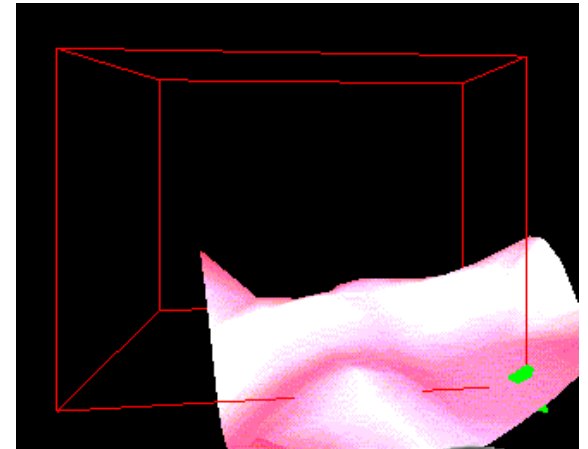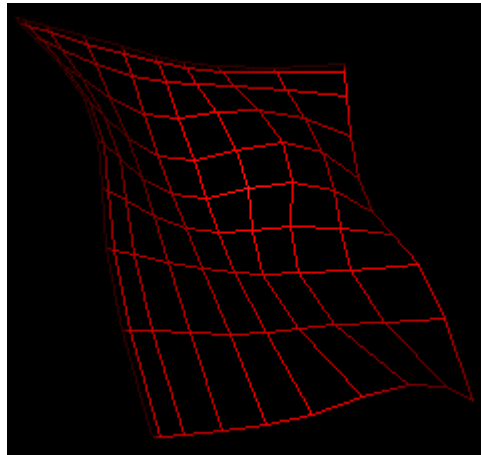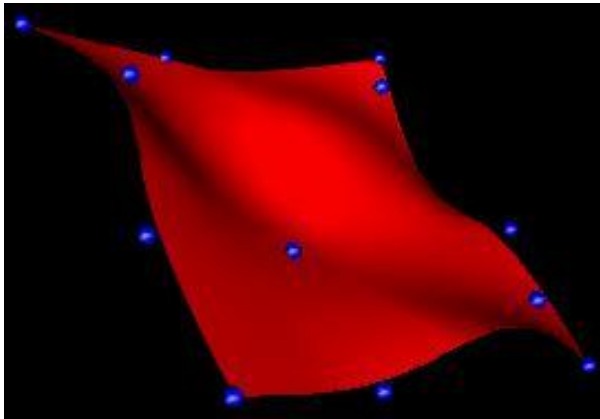
Virtual Assembly Example

- Rudder Pedal Installation
- Complex Geometry
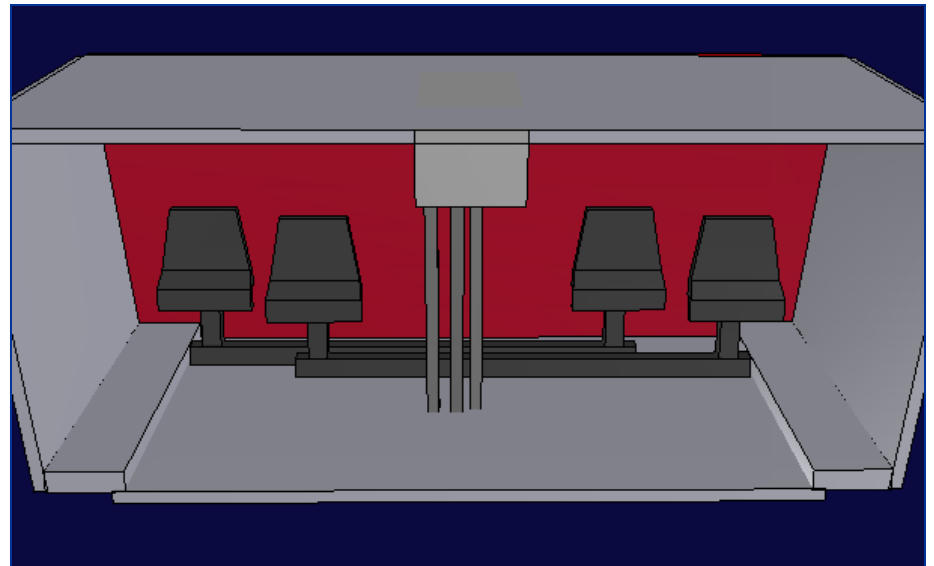
VPS (Voxmap PointShell)

- Rapid collision detection

- Trade accuracy for speed

- Voxel representation

- Dynamic object + static environment

- Physically based modeling
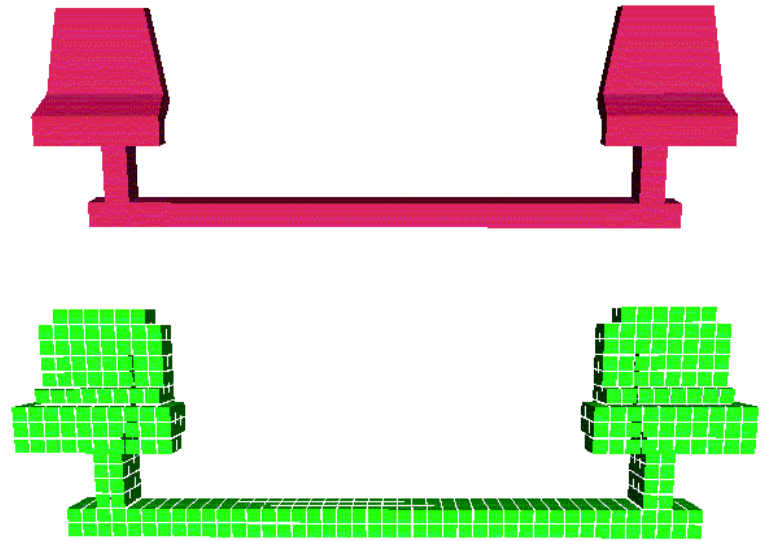
Modified Haptic Process

- Dynamic Object Updated
- VPS Detects Collisions
- VPS Physically Based Modeling Determines Forces
- GHOST queries VPS for position of endpoint and forces

Haptic Servo Loop

Endpoint Position

Update Models

Detect Collisions — **VPS**

Calculate Forces

Return Forces
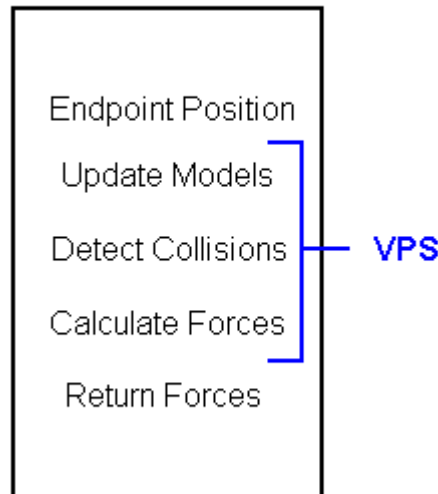
Benefits

- Intuitive part manipulation with haptic feedback

- Easy to investigate interference issues because of immersion

- Easy to collaborate
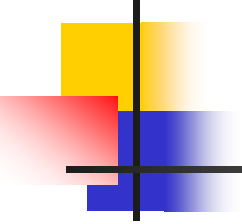
Future Work

- Separate Haptic Computer

- Other Haptic Devices

  - 6 Degree of Freedom PHANToM

  - CyberForce

- Phantom Stand Position/Mobility

- Phantom Volume Geometry

Hydraulic Hose Routing in Virtual Reality

GOAL: To develop a virtual reality design tool that allows designers to accurately route hydraulic hoses early in the product design process.

The Hose Routing Problem

- Difficult to predict installed hose shape
  - Hoses vary in flexibility
  - Installation affects hose shape
  - Operation affects hose shape
- Multiple hoses are needed for many products

- Hose wear occurs when hoses rub against other objects or other hoses
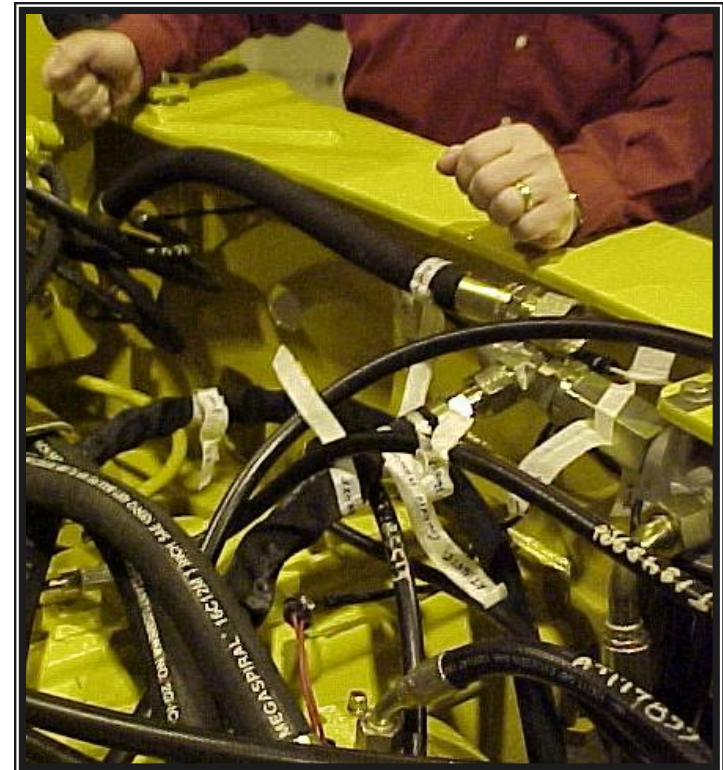
Current State of the Art

- Hoses added to CAD model
  - ProPiping
  - Adams Hose Routing Module

or

- "Enough room" for hoses is left in product design

or

- Expert hose designers take their "best guess" on hose shape for the stiffest or most critical hoses

Why Virtual Reality?

- VR provides a three-dimensional interface to computer models

- Three-dimensional representation of the product design exists early in the design process

- VR allows for natural interaction and examination of spatial relationships

JACK™ Human figure modeling software

Advantages

- Loads CAD geometry
- View geometry in the HMD through JACK's eyes
- Position tracking
- JackScript (Python + JACK)
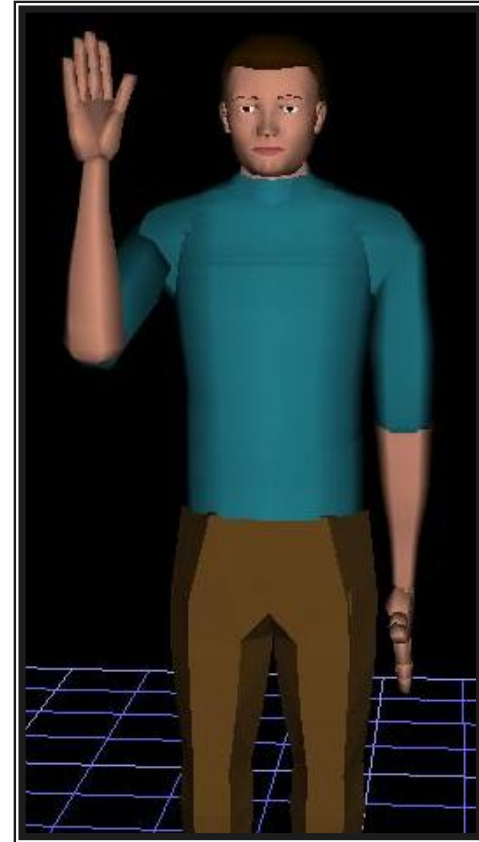
VRHose Hardware
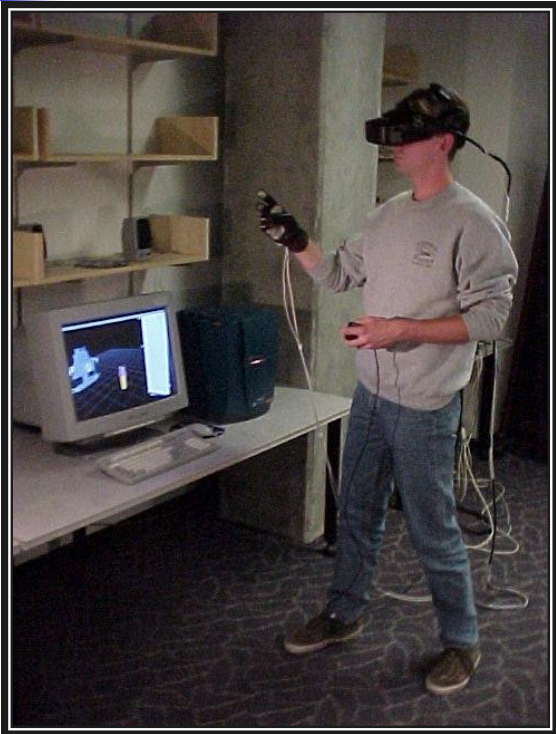
- Virtual Research HMD
- Ascension Flock of Birds Trackers
- Fakespace Pinch Gloves
- Switch Box for menus
- SGI ONYX2 or Octane

VRHose Program

- Series of JackScript code classes
- Geometry loaded from existing CAD models
- Custom menu system
- Analyzes hose shape with ADAMS
- Load and Save hose routes
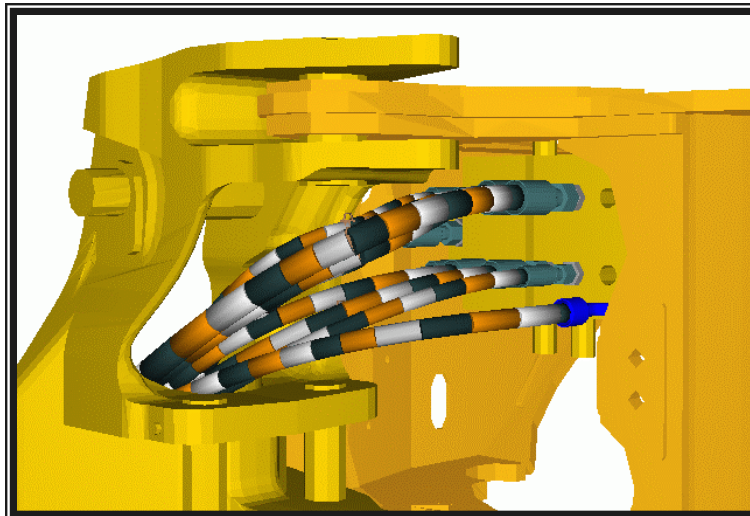
Hose Testing

Axial

Torsion
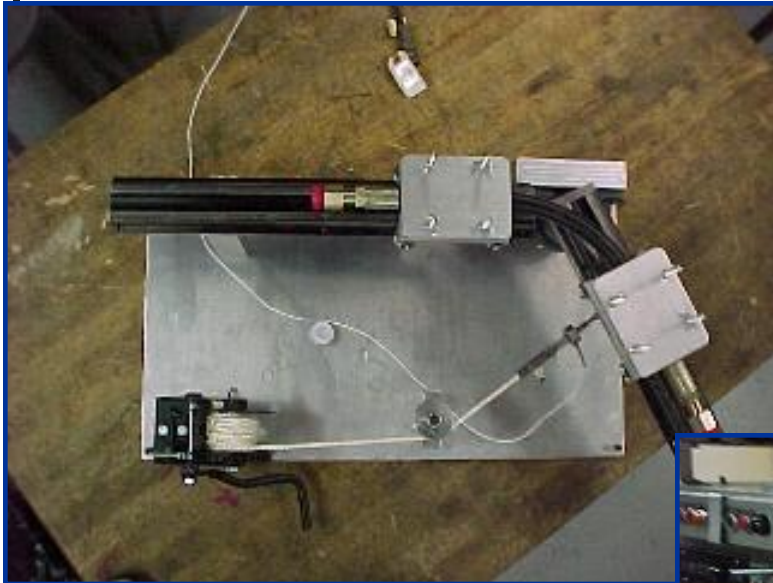
Bending

Hose Modeling

- Hose points
- Clamping constraints
- Physical hose properties
    - Weight per unit length
    - Inside diameter
    - Outside diameter
    - Axial stiffness
    - Torsional stiffness
    - Bending stiffness
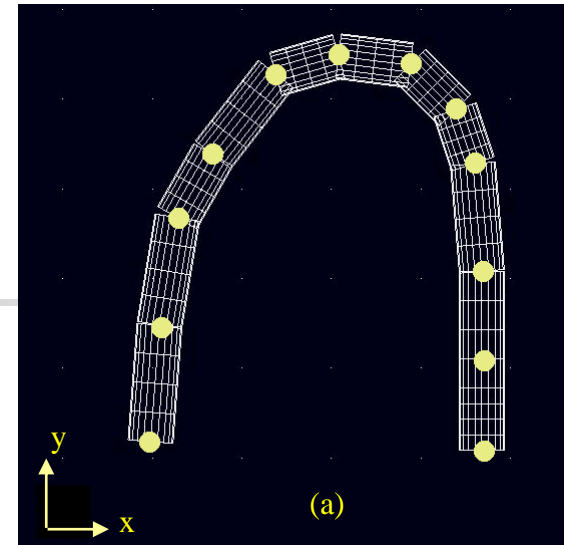
Initial hose points
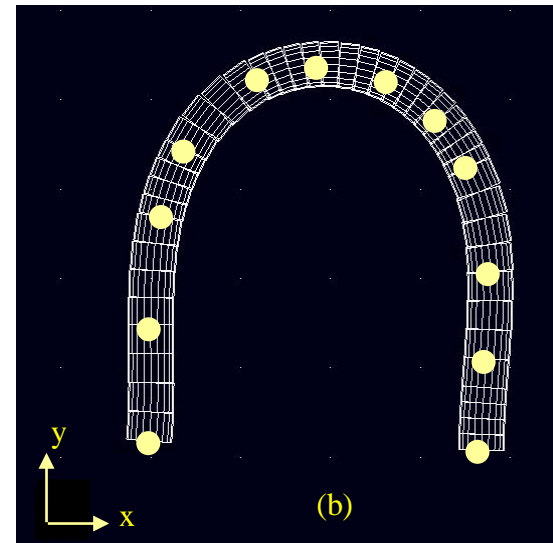
Calculated hose shape

Hose Modeling
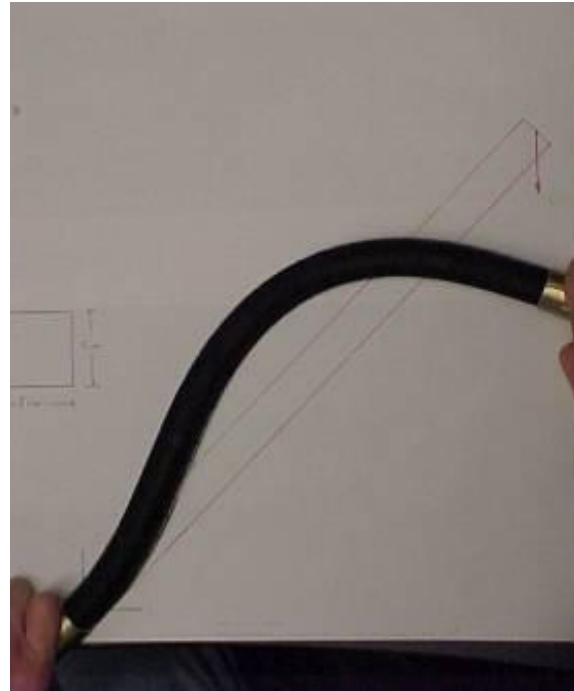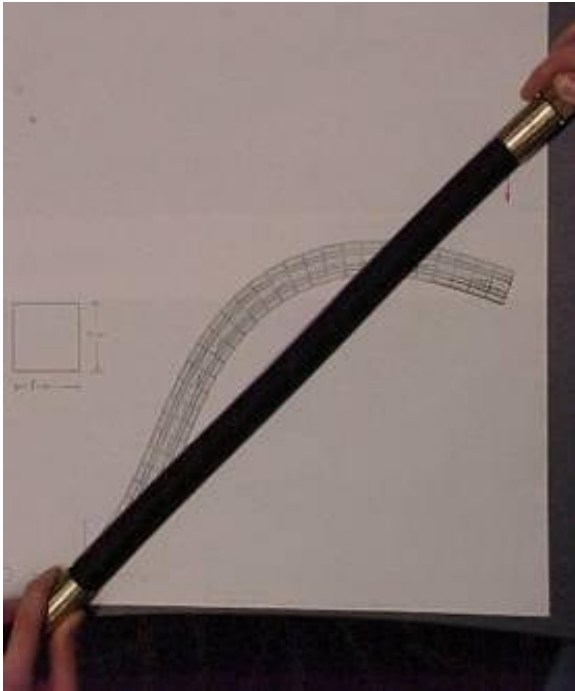
Hose Routing Steps
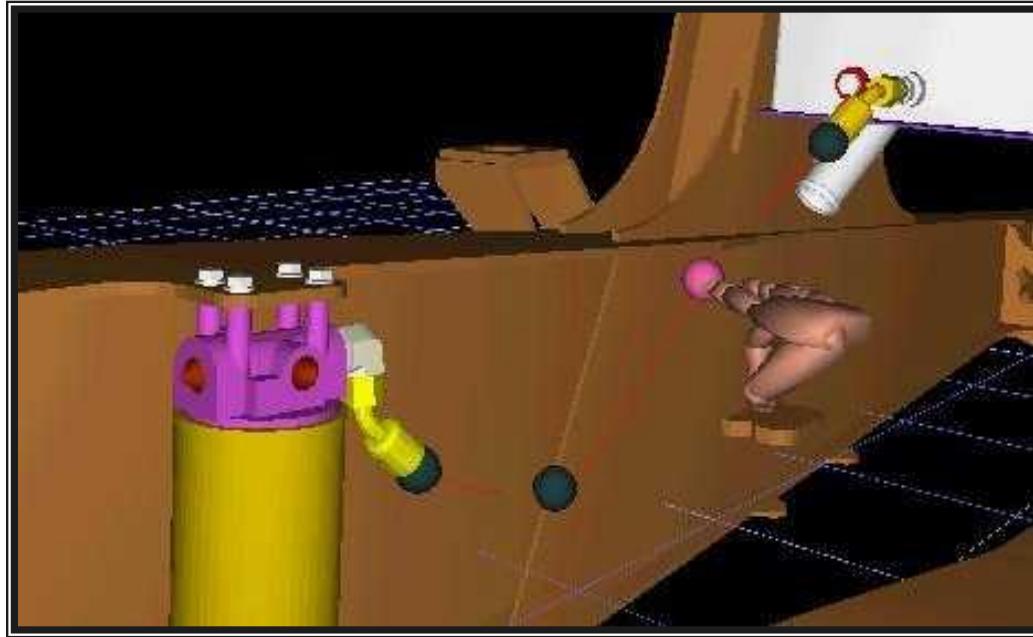
1. Load part geometry and hose port locations
2. Select hose type and size from menu
3. Choose and place connecting hardware
4. Specify hose path with "hose points"

Hose Routing Steps

5. Observe B-spline interpolation of hose path
6. Modify "hose points" as needed
7. Analyze hose path to obtain actual hose route
8. Repeat 6 and 7 until satisfied
9. Save final hose route

Conclusions

- Virtual Reality provides easy interaction and viewing
- Placing and examining hose routes is fast and intuitive
- Hose analysis improved routing design
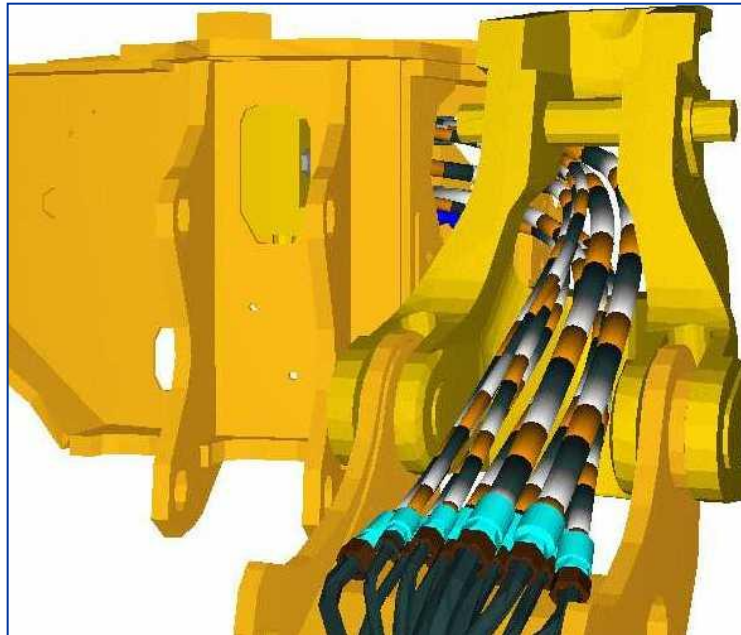
Future Work

- Solve for the swept volume from a moving hose path
- Increase the variety of available hose clamps

Ergonomic Design using 3D Human Anthropometry Data

GOAL: To develop methods for ergonomic design that take advantage of the availability of 3D human anthropometry data.

Traditional Methods of Ergonomic Design

Traditional design uses one-dimensional data sets and the "percentile" approach

95th percentile male
5th percentile female

Traditional Methods of Ergonomic Design

Problems with this approach include:

- Dimensions are specific to the population for which they were calculated

- Only one-dimensional data is used

- Composite humans are used for design, rather than true human representations
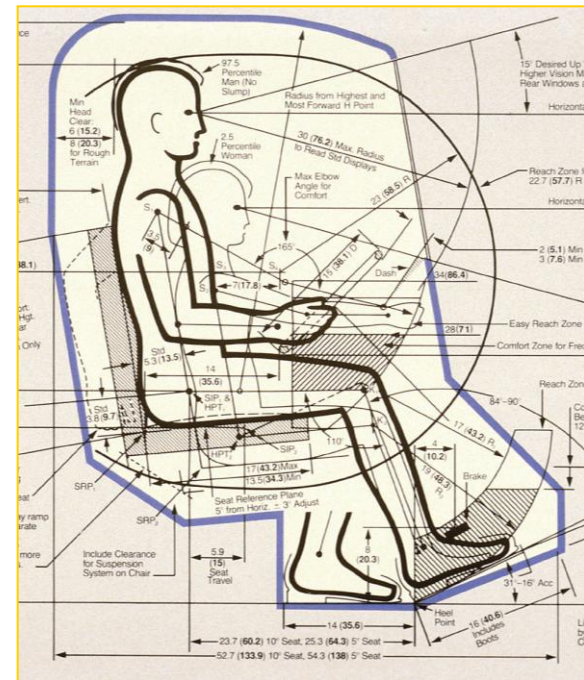
Civilian American and European Surface Anthropometry Resource (CAESAR)

- Anthropometric data for ~4500 civilians in the US and Europe

- 3D (color) surface scans, ~70 anatomical landmark locations

- Standing, seated working, and seated coverage postures
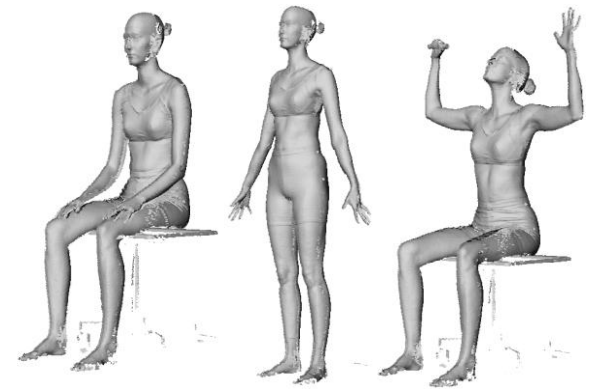
John Deere Survey

- ~80 subjects seated in a John Deere seat

- Dynamic motion path data for the feet and hands

- 12 John Deere subjects participated in the CAESAR project
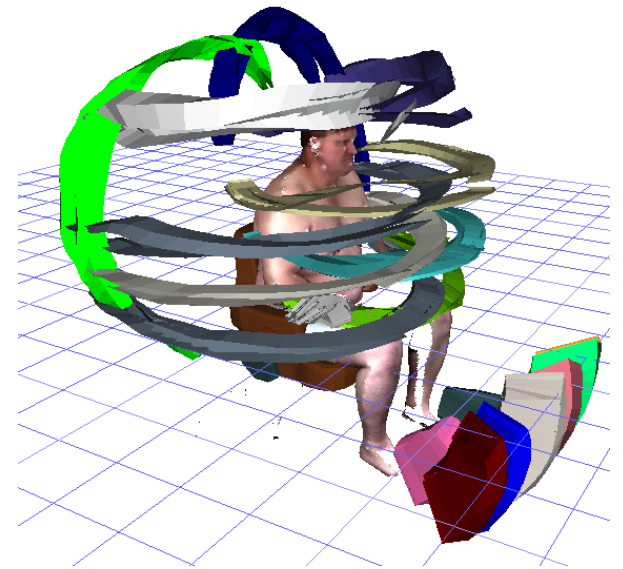
Processing and Viewing Data

Coordinate systems transformations

- John Deere data: Origin located at the seat origin

- CAESAR data: Data transformed based on the "butt block" landmark location

All data aligned such that the seat origin is at the origin of the virtual space

Seat Index Point

176mm

152.7mm

4.9mm

65mm

Seat Origin

Z

26mm

Butt Block

Y

(Performer coordinate system)

The Scene Graph

```
                            The Scene Graph
        ┌──────────────────────────┼──────────────────────────┐
  ┌───────────┐            ┌───────────┐            ┌───────────┐
  │Subject 1121│           │Subject 1122│           │Subject 1123│
  │  SWITCH   │            │  SWITCH   │            │  SWITCH   │
  └───────────┘            └───────────┘            └───────────┘
        │                        │                        │
                         ┌───────────────┐
                         │ Subject 1122  │
                         │TRANSFORMATION │
                         └───────────────┘
            ┌────────────────────┼────────────────────────┐
     ┌─────────────┐      ┌───────────┐          ┌──────────────┐
     │Landmark Set │      │ LineMan   │          │Motion Path Set│
     │   SWITCH    │      │  SWITCH   │          │   SWITCH     │
     └─────────────┘      └───────────┘          └──────────────┘
       ┌──────┴──────┐          │              ┌──────────┴──────────┐
  ┌─────────┐  ┌─────────┐ ┌──────────┐  ┌──────────────┐  ┌──────────────┐
  │ Landmark│  │ Landmark│ │ LineMan  │  │RH Above Head │  │LH No Arm Rest│
  │ SWITCH  │  │ SWITCH  │ │ GEOMETRY │  │  GEOMETRY    │  │  GEOMETRY    │
  └─────────┘  └─────────┘ └──────────┘  └──────────────┘  └──────────────┘
       │            │
  ┌─────────┐  ┌─────────┐
  │ Landmark│  │ Landmark│
  │ GEOMETRY│  │ GEOMETRY│
  └─────────┘  └─────────┘
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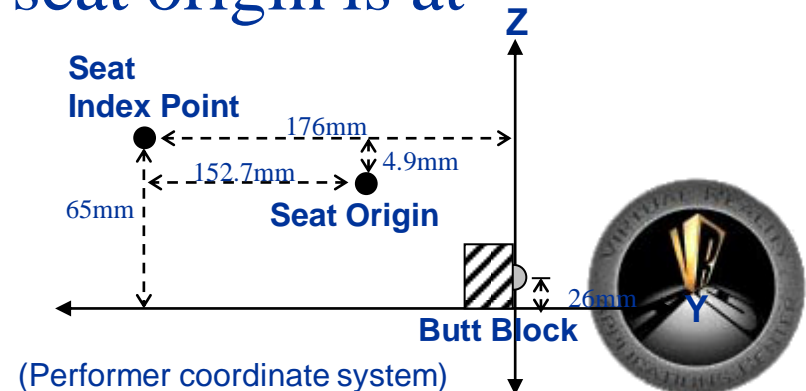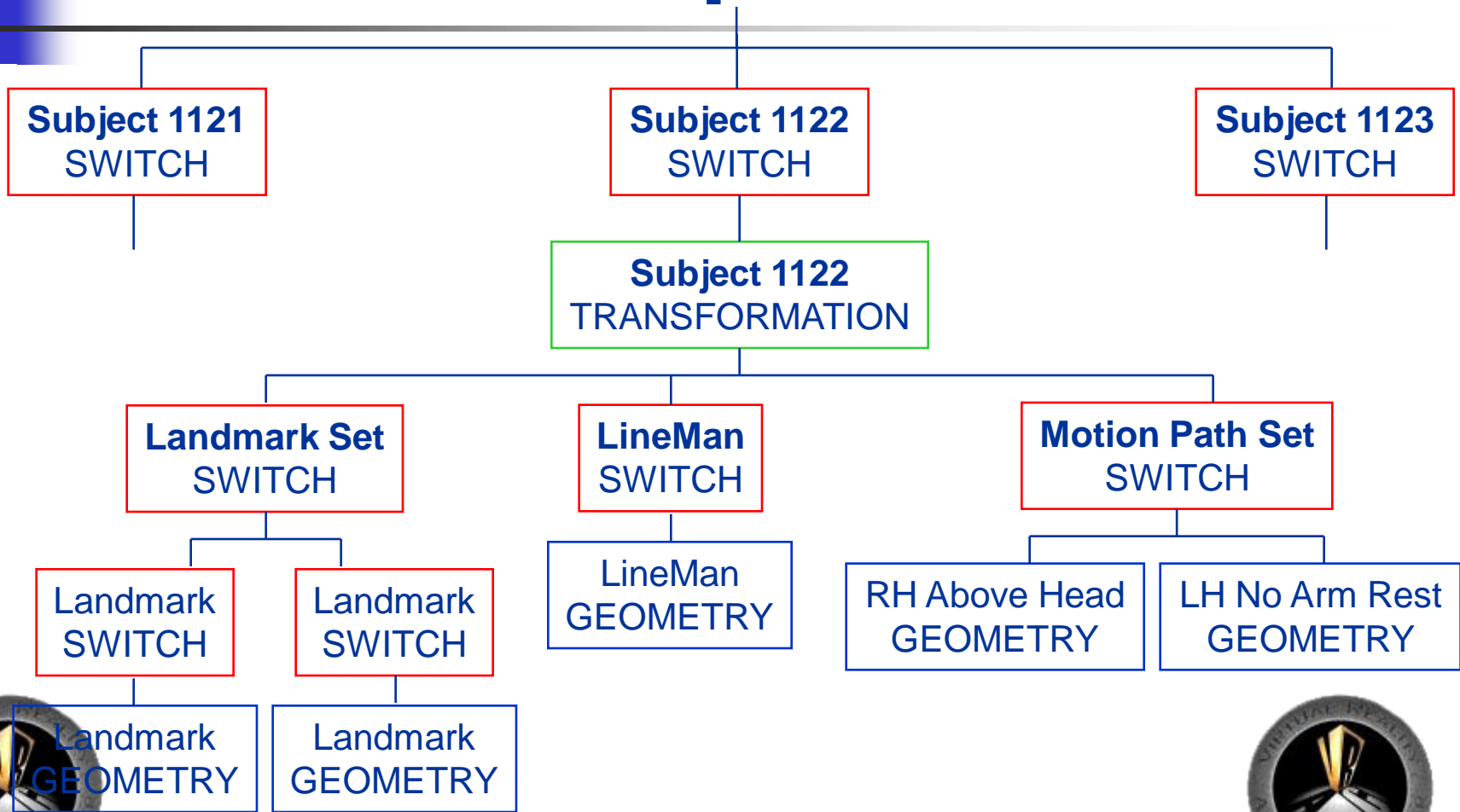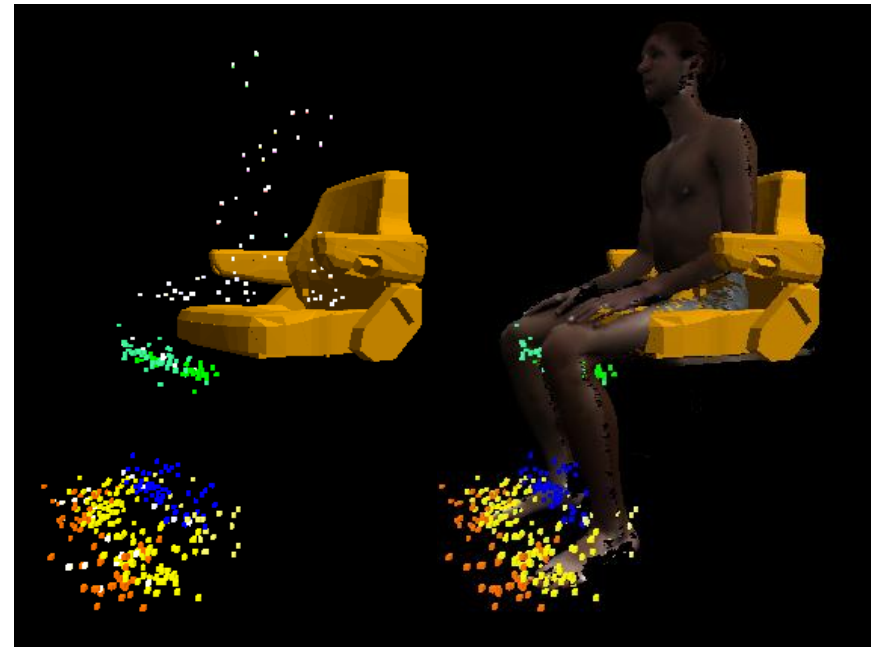
Application Features
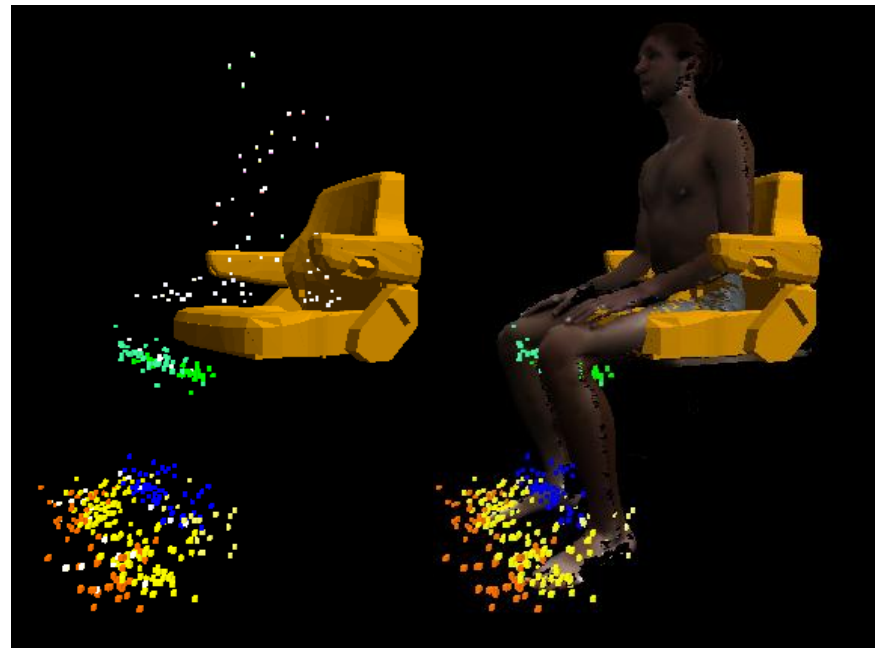
Use of existing CAD geometry

- Added to the scene graph and easily translated, rotated, scaled within the application

Application Features

Element selection within
the scene graph

- Designer may display
  complete set of data for
  specific population,
  one subject, or data
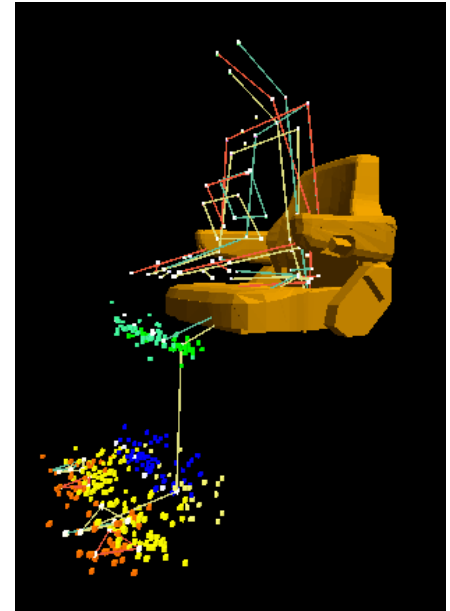 relevant to the design

- Determine
  representatives or
  "outliers"

Posture Data Examination

Posturing information discernable through LineMen option

- Connect maximal surface landmark locations

- Connections specified by the designer

Allows greater visibility of the individual within the population

Discussion

Immersive application enables the use of current and future 3D anthropometric data sets

anthro-cab_paths.m1v

Discussion

- No synthetic human representatives, not a human figure poser; designs based on population data and selected individuals

- A population can be viewed in reference to a workstation layout allowing for rapid prototyping and accommodation of anthropometric differences

Future Work

- Allow view to switch from third-person view to assume a particular subject's view (first-person mode)

- Allow for the ability to save selected scene elements and workstation configurations

- Provide filtering based on demographic data

- Add a joint-center model to facilitate posing of the landmark and scan data

Acknowledgements

More Information

www.vrac.iastate.edu

www.vrac.iastate.edu/~jmvance

www.vrjuggler.org