Emerging Applications of VR

Electrical and Computer Engineering Dept.
Emerging applications of VR

✓ In manufacturing (especially virtual prototyping, assembly verification, ergonomics, and marketing);

✓ In robotics (programming, teleoperation, space robotics);

✓ In data visualization (volume visualization, oil and gas exploration, volumetric displays);

✓ Other areas.
VR penetration in non-medical fields

(UK VR Forum survey, 2000)

<table>
<thead>
<tr>
<th>Industry</th>
<th>% - companies using, Experimenting or Considering VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil &amp; Gas</td>
<td>46%</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>29%</td>
</tr>
<tr>
<td>Engineering Contractors</td>
<td>26%</td>
</tr>
<tr>
<td>Construction</td>
<td>24%</td>
</tr>
<tr>
<td>Aerospace &amp; Defence</td>
<td>22%</td>
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<tr>
<td>Automotive</td>
<td>22%</td>
</tr>
<tr>
<td>Retail</td>
<td>21%</td>
</tr>
<tr>
<td>Consumer Products</td>
<td>20%</td>
</tr>
<tr>
<td>Power Gen/Distribution</td>
<td>11%</td>
</tr>
<tr>
<td>Chem/Pharmaceuticals</td>
<td>10%</td>
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</tbody>
</table>
Classes of VR applications

(UK VR Forum survey, 2000)
Main benefits of using VR

(UK VR Forum survey, 2000)

- Improved communications: 24%
- Better decision making: 11%
- Greater efficiency: 10%
- Fewer physical prototypes: 10%
- Fewer mistakes: 7%
- Lower production costs: 5%
- Faster time to market: 4%
- Improved functionality: 3%
- Greater competitiveness: 3%
- Improved quality: 3%
VR in Manufacturing

VR Manufacturing Applications

- Ergonomic Analysis
- Plant Design
- Training, Maintenance
- Marketing
- Assembly Validation
- Virtual Prototyping
**GHOST Free Form Application**

- Free Form sculpting is a new type of Human-Computer interaction;
- It functions as a convenient GUI that sits on top of the GHOST library;
- The GUI is based on static and dynamic bar menus “dynabars”;  
- It allows model export to CAM machines for rapid prototyping, as well as to animation packages for computer character animation.
- Requires dual Pentium II (> 300 MHz), 512 MB RAM, high-end hardware graphics acceleration, 1024x768 screen resolution (or better).
The center block is “digital clay”
FreeForm wire-cut mode

Wire Cut Menu

<table>
<thead>
<tr>
<th>Icon</th>
<th>Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="hand.png" alt="icon" /></td>
<td>Hand Tool</td>
<td>Select and move or edit objects.</td>
</tr>
<tr>
<td><img src="pencil.png" alt="icon" /></td>
<td>Pencil</td>
<td>Draw pencil marks on the sketch plane as a guide for sketch elements.</td>
</tr>
<tr>
<td><img src="eraser.png" alt="icon" /></td>
<td>Erase All Pencil Marks</td>
<td>Erase all pencil marks from the sketch plane.</td>
</tr>
<tr>
<td><img src="line.png" alt="icon" /></td>
<td>Draw Line</td>
<td>Draw a line on the sketch plane.</td>
</tr>
<tr>
<td><img src="arc.png" alt="icon" /></td>
<td>Draw Arc</td>
<td>Draw an arc on the sketch plane.</td>
</tr>
<tr>
<td><img src="circle.png" alt="icon" /></td>
<td>Draw Circle</td>
<td>Draw a circle on the sketch plane.</td>
</tr>
<tr>
<td><img src="rectangle.png" alt="icon" /></td>
<td>Draw Rectangle</td>
<td>Draw a rectangle on the sketch plane.</td>
</tr>
<tr>
<td><img src="curve.png" alt="icon" /></td>
<td>Draw Freehand Curve</td>
<td>Draw a freehand curve on the sketch plane.</td>
</tr>
<tr>
<td><img src="done.png" alt="icon" /></td>
<td>Done</td>
<td>Complete an operation and return to Sculpt Mode.</td>
</tr>
<tr>
<td><img src="cancel.png" alt="icon" /></td>
<td>Cancel</td>
<td>Cancel the last wire cut operation and return to Sculpt Mode.</td>
</tr>
</tbody>
</table>
Free Form wire cut

Drawing on the cut plane

Clay after Outside wire cut

Clay after Inside wire cut

Cut Inside button

Cut Outside button

Free Form wire cut
Example – Making of Saint Fruition

Artist’s sketch

Rough initial clay model
Example – Making of Saint Fruition

Finished body (clay)

Wire cut arrow for support (clay)

Finished support (clay)
Example – Making of Saint Fruition

Digital clay statue

5 ft Aluminum statue
Example – Making of Saint Fruition

Statue model used for animation (Maya)

Key frame animation of statue

Textured statue used for animation (Maya)
Assembly verification

✓ Another stage in product development when the prototype is made of several parts;
✓ University of Washington developed the “Virtual Assembly Design Environment to verify CAD design assemblies;
✓ Parts geometry and attributes are imported from CAD into VADE then the assembly is analyzed and robots are programmed

Design modification in VR

Collision detection through swept volumes
Parts making up car exterior have varying tolerances. Tighter tolerances are more esthetically pleasing but also cost more.

What is good enough? Inspection is done in inspection rooms using stripped lights.

Same can be done on a virtual car ahead of real production.
Assembly verification

Researchers in UK developed the Visualization of the Impact of Tolerance Allocation (VITAL) and tested it on a prototype Rover R75;

They constructed several models with various tolerances; by shining the virtual car body with stripped light looking at discontinuities;

Unacceptable tolerances discovered in the virtual inspection room
Jack is an intelligent agent humanoid used in ergonomic analysis; the Task Analysis Toolkit computes lower-back effort and energy consumption – relates to worker fatigue.
✓ Once a prototype is done, it has to be tested for ease of use (ergonomic analysis);
✓ One such product is *VirtualANTHROPPOS* developed in Germany to test the ease of use of tractor cabins
✓ An avatar controlled by the user is interacting with the virtual cabin while the system computes joint discomfort levels using ERGONAUT (an ergonomic analysis tool)
Ergonomic Analysis

✓ Another use of VirtualANTHROPOPOS is to visualize reach envelopes; The user can drive the avatar in real time using a wireless body suit;
Personnel Training

✓ Training in airplane maintenance – task has a cognitive component (manuals) and a tool/part manipulation component – and they are sequential.
Personnel Training

✓ Task-related information is placed directly in the scene using augmented reality. Results in faster information retrieval and enhanced associative memory. System uses vision-based tracking to recognize worker’s view and places text in relation to objects;
Training system detect removal of cover and labels parts underneath; then it detects the cap was removed and changes dynamically the text to “4. Press to test”. If the test fails then additional areas of interest are highlighted (“Filter Bypass”)

1. Remove cover
2. Set all controls to OFF or ZERO before test
3. "Check bypass"
4. Press to test
VR Marketing Applications

Citröen uses virtual showrooms
VR Marketing Applications
VR Marketing Applications
VR applications in Robotics/manufacturing relate to several areas:

- CAD design and robot programming, making the process more intuitive;
- Teleoperation (control at a distance) alleviating problems related to poor visibility and large time delays;
- Multiplexed teleoperation, acting as a filter of particular robot kinematics;

Robots are also used in VR in haptic interfaces (discussed earlier in our course).
The “multi-modal teaching advisor helps novice operators program welding paths for industrial robots;
It runs on a PC networked with trackers and laser range finder;
Calculates the difference between the pre-computed (optimal) path and user’s input on the teach pendant. This is presented graphically on the user’s HMD. (Burdea, 1999)
Robotic programming - continued

- Research done in Germany for off-line robot programming done in VR, with the programmer immersed in the task he is programming;
- The programmer specifies the trajectories, and the simulation performs optimized collision detection;
- Validation is done at run time when the real robot is controlled using the same computer and real sensor data is used to fine-tune the VR-generated program.

(Burdea, 1999)
Research at University of Tokyo for the teleoperation of robots in smoke-filled remote environments. Over-imposes the visual scene from the remote robot with the virtual scene of a kinematically identical robot. Thus VR acts as a guide to allow teleoperation.
Research at NASA developed a VR-based teleoperation to allow operation despite large time delays. Works by controlling a “phantom robot” which responds instantaneously to the operator. Allows preview of the move, before it is executed.
Teleoperation with large time delays - continued

✓ Research at NASA drove the Mars rover using VR-based teleprogramming;
✓ This was used to send high-level macro commands based on the simulation of a virtual rover on a virtual Mars surface. This overcame a 20 minute time delay!
Researchers in Germany developed a way to naturally controlling robots through avatars;

The users is immersed in VR and sees a scene with avatars to which he is mapped;

He interacts through gestures (measured by a sensing glove)
A real robot then interacts with the remote real environment; if the task is visual inspection then real images from the remote site can be overlaid on the virtual scene, and thus seen by the user;
Research at Jet Propulsion Lab (California) allows the teleoperation of a remote robot indirectly by controlling a motion-guide trajectory, which the robot is then constrained to follow. (Burdea, 1999)
VR Robotics Applications - continued

✓ Research at University of Paris to allow multiplexed (one-to-many) teleoperation of kinematically dissimilar robotic arms;
✓ VR acts as a high-level filter masking the detailed slave robot configuration; Translator then converts user actions to robot actions.

(Burdea, 1999)
✓ Represents the transformation of abstract data into 3D scenes;
✓ The information visualization pipeline allows the user to control the view to the scene using an input device and select an area of interest;
✓ The data extraction loop is asynchronous, so as to maintain interactivity. It reads user input from a FIFO buffer;
✓ Time-varying data represent a complex case, as user time may not coincide with the time clock used in visualizing the time-dependent data.
In this class we learned about surface-based (polygonal or spline) rendering only. This leaves the interior of virtual objects hollow;

Volume graphics renders the surface as well as the interior of objects, called “voxels.”
Ray casting to create a 2-D image from volumetric data

View Plane

Tri-linear interpolation

Rays

Calculate gradients and lighting
Volumetric graphics advantages

✓ Much richer dataset;
✓ Objects appear more real;
✓ Can be displayed on same displays as surface-based models

Volumetric graphics disadvantages

✓ Much larger memory requirement (order of GB);
✓ Requires special boards to be real-time;
✓ Require special displays if auto-stereoscopy is desired;
✓ Much less used today – small software support base.
Volumetric graphics
**Volumetric Graphics Hardware**

- Consist of volumetric rendering boards and of volumetric displays;
- VolumePro 1000 is a graphics accelerator sold by TeraRecon Inc. renders 512 x 512 x 512 voxels at 30 frames/second using a Mitsubishi chip.
- For surface geometry data it works together with the graphics board installed on the same PC.
VolumePro Rendering Pipeline

✔ VolumePro 1000 processed the 3D data through ray casting from a view plane.
✔ Rays pick up color and opacity information by tri-linear interpolation to the nearest lattice point
✔ Gradients are then computed
Early models used LED matrix panel that translates back-forth on rails; User can see stereo with bare eyes.

Due to eye inertia, the image appears to float in space;

But they had low resolution, noisy, monochrome (red LEDs);

Did not have a 360° viewing area
The display produces 200 disk-shaped slices each refreshed at 20 Hz;
Resolution 768x768, 8 colors;
10”-diameter spherical image;
360º x 180º viewing angle.
Auto-stereoscopic 3-D Display produced by Actuality Systems
New Interaction Techniques with Volumetric Displays

(Balakrishnan et al, 2001)