ML2VR
Providing MATLAB Users an Easy Transition to Virtual Reality and Immersive Interactivity

David J. Zielinski     Ryan P. McMahan     Wenjie Lu     Silvia Ferrari
Motivation:

DiVE: Duke Immersive Virtual Environment. 6-Sided CAVE-type Virtual Reality System

Benefits of using Virtual Reality
- Represent models to scale
- Increased spatial understanding
- Advanced interaction techniques
- Collaborative exploration (CAVE-type systems)

(Open House Every Thursday 4:30pm)
Motivation:

Engineering Students  \(\rightarrow\)  DiVE
Question: What software do engineers use for simulation and modeling?
"MATLAB is a numerical computing environment and programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, and implementation of algorithms." -Wikipedia
Our Goal:

MATLAB  

DiVE
## Potential Existing Solutions:

<table>
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<tr>
<th>Name</th>
<th>Features</th>
<th>Issues</th>
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<td>MATLAB Simulink 3D Toolbox</td>
<td>Create and modify VRML scenegraphs.</td>
<td>Targeted at Desktop display systems.</td>
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### Our Solution:

```
MATLAB ← ML2VR ← Syzygy
```
Let's see ML2VR in action!
# Common VR System Topologies

<table>
<thead>
<tr>
<th>Topology</th>
<th>Description</th>
<th>University</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 CPU → 1 HMD</td>
<td></td>
<td>University of Texas at Dallas</td>
</tr>
<tr>
<td>1 CPU → 4 Projectors</td>
<td></td>
<td>University of Indiana</td>
</tr>
<tr>
<td>1 CPU → 1 Projector</td>
<td></td>
<td>Duke University</td>
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What is OpenGL?

"OpenGL is an API (Application Programming Interface) for rendering 2D and 3D computer graphics. The API is typically used to interact with a GPU, to achieve hardware-accelerated rendering. OpenGL was developed by Silicon Graphics Inc. in 1992." -Wikipedia

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<th>MATLAB</th>
<th>OpenGL</th>
<th>Screen</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>fill3([0 0 0],[1 0 0],[1 0 1],</code></td>
<td><code>glBegin(GL_TRIANGLES)</code></td>
<td>vertex = corner</td>
</tr>
<tr>
<td></td>
<td><code>glVertex3f(0,0,0);</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>glVertex3f(1,0,0);</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>glVertex3f(1,0,1);</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td><code>glEnd();</code></td>
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What does OpenGL intercept mean?

1. We add our replacement opengl32.dll to the MATLAB directory.
2. At runtime, MATLAB now loads our replacement opengl32.dll.
3. When MATLAB calls an opengl function, our function gets called.
4. After sending out the data, we pass the data onto the real opengl32.dll function.
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MATLAB command

cplxmap(...) → glVertex3f(...) → glVertex3f (...) { // send to GPU }

normal case
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System Architecture Challenges

- Complicated MATLAB simulations may run at low frame rate.
- Our Syzygy content viewer runs at a higher frame rate.
- Can we utilize this "frame rate mismatch?"
Detailed System Architecture

Graphics content is generated by MATLAB simulation

That content is displayed by our Syzygy viewer
MATLAB simulation generates content

Syzygy viewer receives a content frame

While waiting for new content, Syzygy viewer allows user to view content from different viewpoints (head based rendering).

Fast head based rendering = reduced simulation sickness
MATLAB Script

vr = vr_interface(ServerIP,ServerPort);

while 1
    [event,btn,pos]=vr.get_button_event();
    if event==1 && btn==0
        % modify data here
    end

    clf; % clear screen
    surf(dataX,dataY,dataZ); % render surface
    drawnow; % flush
end

● Minimal additions to access data from VR devices
**Programming API**

\[ vr = vr\_interface(ServerIP,ServerPort); \]

**Parameters:**

- \( vr.set\_return\_type(value) \)
- \( vr.set\_transform\_matrix(value) \)

**Events:** helps with low frame rate simulations

- \([event, button, pos3]=vr.get\_button\_event()\)
- \([event, axis, pos3, val]=vr.get\_joystick\_event()\)

**Polling:**

- \([matrix4]=vr.get\_sensor\_state(sensorID)\)
- \([val]=vr.get\_button\_state(buttonID)\)
- \([val]=vr.get\_joystick\_state(axisID)\)

**Navigation:**

- \( vr.do\_navigation\_translate(vec3) \)
- \( vr.do\_navigation\_rotate(obj, vec3, amount) \)
Case Study: Robot Path Planning

- Artificial potential function used to plan the motion of the robot
- Potential function recalculates the best path to the target while adapting to the dynamic addition and removal of obstacles.
- We added in ML2VR functions to make the simulation interactive.

New Features Robot Demo

Move the goal

Raycasting
New Sci Vis Examples

coneplot and streamline (complicated 3D visualization)

surf demo with parameter modification with joystick x-axis
Interaction Examples

01_click
02_joystick
03_touch
04_drag_pos3
05_drag_matrix4
06_virtual_hand_pos3
07_virtual_hand_matrix4
08_raycasting
09_sphere_spawner
10_polling
11_navigation
Contributions:

- Open source cross-platform software system.
- MATLAB scripts can easily obtain input device data.
- Decoupled (fast) head based rendering.
- Successful case study of a desktop to VR conversion.
- Suite of Interaction programming examples.
## March is ML2VR Month!

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<tr>
<th>What</th>
<th>Where</th>
<th>When</th>
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<tbody>
<tr>
<td>Friday Forum Talk</td>
<td>Duke University</td>
<td>March 8th</td>
</tr>
<tr>
<td>Poster Session @ FIP Symposium</td>
<td>Duke University</td>
<td>March 10th-11th</td>
</tr>
<tr>
<td>Poster @ IEEE VR 2013</td>
<td>Orlando, Florida</td>
<td>March 16th-23rd</td>
</tr>
<tr>
<td>Invited Speaker @ &quot;Immersive Visualization Bootcamp&quot;</td>
<td>Indianapolis, Indiana</td>
<td>March 25th-27th</td>
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</table>
Future Work

Software Robustness
- More OpenGL primitives
- Dynamic buffers
- Line rendering issues
- Desktop simulator refinement

Evaluation
- What is the benefit of immersive visualization and interaction for MATLAB?
Future Work
Robotics Applications

Quadcopter Simulation

Human-Robot Collaboration Simulation
Future Work  Front + Back Ends

MATLAB  ML2VR  Syzygy

R

Mathematica
Camille Goudeseune
University of Illinois

Bill Sherman
Indiana University

FreeVR

VR Juggler
Judy Vance
Iowa State University
Michael "Gus" R. Gustafson

Teaches EGR 53L, a Computational Methods in Engineering w/ MATLAB course, that is required for all Pratt (Duke Engineering) first-year students.

Ross Tredinnick

Living Environments Laboratory (UW Madison CAVE)

Regis Kopper

New director of the DiVE.
Thank You!

Questions?

djzielin@duke.edu

http://sourceforge.net/projects/ml2vr/