VPython Architecture

Bruce Sherwood
Emeritus Professor, Department of Physics
North Carolina State University

Ruth Chabay
Professor, Department of Physics
High Point University

The development of VPython was funded in part by the National Science Foundation (grant DUE 0237132). Opinions expressed are those of the authors, and not necessarily those of the foundation.
Empowering Nonexpert Programmers

- VPython: Python programming language plus 3D graphics
- Novice programmers can create navigable real-time 3D animations
- Main users: students, educators, researchers
Examples of VPython Programs

- A complex program can run in multiple environments
- A simple program
  - Intelligent defaults
  - Vector computations
  - 3D animations as side effects of computations
- Can embed in web pages
VPython 7

Local server
- Python
- vpython module
- HTTP server
- websocket server
- other Python modules
- user program

Browser
- JavaScript process
- GlowScript graphics library
- WebGL
- web page
VPython 7 with Jupyter Notebook

Local server
- Python
- vpython module
- Jupyter browser communication
- other Python modules
- user program

Browser
- JavaScript process
- GlowScript graphics library
- WebGL
- notebook

Communication between Local server and Browser

A diagram illustrating the integration of VPython 7 with Jupyter Notebook, showing the flow of communication and components involved.
GlowScript VPython
(all in browser)

Use RapydScript-NG to compile Python to JavaScript

Browser

JavaScript
GlowScript graphics library

WebGL
web page
Operator Overloading: How Vector Addition Works

- Using the PaperScript library with the Acorn parser of JavaScript, convert
  \[ a + b \Rightarrow a[\text{`+`}](b) \]

- JavaScript permits changing the behavior even of built-in classes such as Number and String

  - String.prototype[\text{`+`}] = function(r) { return this + r }

  - Number.prototype[\text{`+`}] = function(r) {
      return (r instanceof vec) ? add_error() : this + r }

  - vec.prototype[\text{`+`}] = function(r) {
      return (r instanceof vec) ?
          new vec(this.x + v.x, this.y + v.y, this.z + v.z) add_error() }
GlowScript Rendering of 3D images

About 60 times/sec:

Send object data to WebGL

GPU “vertex shaders” → GPU rasterizer → GPU “fragment shaders” → Web page
Animation Loop

• rate(200): no more than 200 loop iterations/s
• About 60 renders/s
• Sleep for remaining time
• Assigning to an object attribute (pos, size, etc.) sets a “changed” flag for that object, and at render time its current attributes are repackaged to send to GPU
• Five 4-vectors: pos, axis, size, color, up, with texture, opacity, shininess, emissive packed into 4\textsuperscript{th} slots; total of 80 bytes per object instance
Object Models in GPU Memory

- A “model” box object is stored in GPU memory
- Represented by 12 triangles, each described by 3 vertex objects specifying position, normal, color, and texture coordinates
- Data for a particular box (an instance of the box class) plus model information is sufficient for the GPU to display that box appropriately in 3D
- GPU memory has models of a box, sphere, cylinder, cone, and pyramid; compounds treated like primitives
- Arbitrary objects built from triangles; extrusions, 3D text
Speed Issues

- Python is an interpreted language and so execution is significantly slower than compiled languages.
- Computationally intensive GlowScript VPython programs run about an order of magnitude faster than VPython 7 programs, because they are compiled to (fast) JavaScript (but there is no access to Python modules).
Additional Technical Details

• Portions of objects hidden behind other objects are not seen thanks to “z-depth” blocking by GPU hardware
• Transparency handled by “depth peeling” algorithm
• Mouse “picking” uses false colors
Major Contributors to GlowScript VPython and VPython 7

- David Scherer: originator of VPython; major contributions to the start of the GlowScript project
- John Coady: originator of Jupyter VPython
- Matt Craig: installers for VPython 7
Brief History

• 2000: Classic VPython created by David Scherer, an undergraduate student at Carnegie Mellon University, in collaboration with Chabay and Sherwood
• 2011 GlowScript begun by Scherer and Sherwood
• 2014 GlowScript VPython by Sherwood
• 2015 Jupyter VPython begun by John Coady
• 2016 VPython 7: Jupyter VPython made consistent with GlowScript VPython by Chabay and Sherwood, in collaboration with Coady; Classic VPython no longer supported

See brucsherwood.net for a detailed history
For More Information

- **vpython.org** – obtaining and using VPython
- **glowscript.org** – full VPython documentation, many examples
- **trinket.io** – embed both editing and execution of VPython in your own web page
- **matterandinteractions.org** – calculus-based contemporary intro physics curriculum in which VPython plays an important role
- **matterandinteractions.org/student** – includes a large number of physics demo programs written in VPython