VPython Architecture

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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
  • Well-designed defaults
  • Vector computations
  • 3D animations as side effects of computations
• Can embed in web pages
Web VPython

This architecture is also used by trinket.io
VPython in Python Installations

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

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

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

Browser
- JavaScript process
- WebGL
- notebook
- GlowScript graphics library
Web VPython: Compilation Details

User code (Python) → Pre-processing → RapydScript-NG → Operator overloading → Post-processing → Executable
Operator Overloading: How Vector Addition Works

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

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

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

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

- `vec.prototype[‘+’] = function(r) {
    return (r instanceof vec) ?
    new vec(this.x + v.x, this.y + v.y, this.z + v.z) add_error() }`
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 4th 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 Web VPython programs run several times 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 Web 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
- Steve Spicklemire: restructuring webpython.org to use Python 3 for the server side
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 Web VPython by Sherwood
• 2015 Jupyter VPython begun by John Coady
• 2016 VPython 7: Jupyter VPython made consistent with Web VPython by Chabay and Sherwood, in collaboration with Coady; Classic VPython no longer supported

See brucesherwood.net for a detailed history
For More Information

• vpython.org – obtaining and using VPython
• webvpython.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