

VPython Architecture

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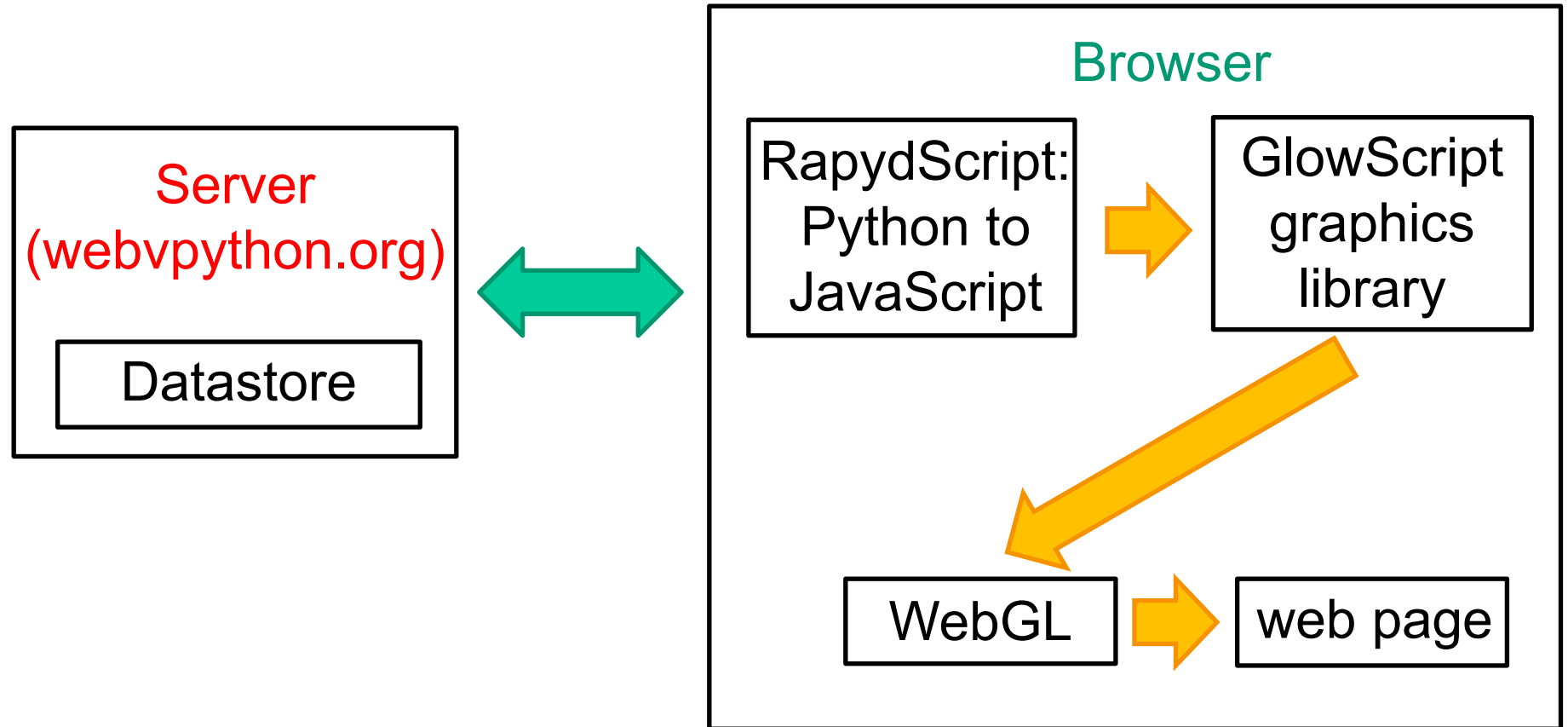
Empowering Nonexpert Programmers

- 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

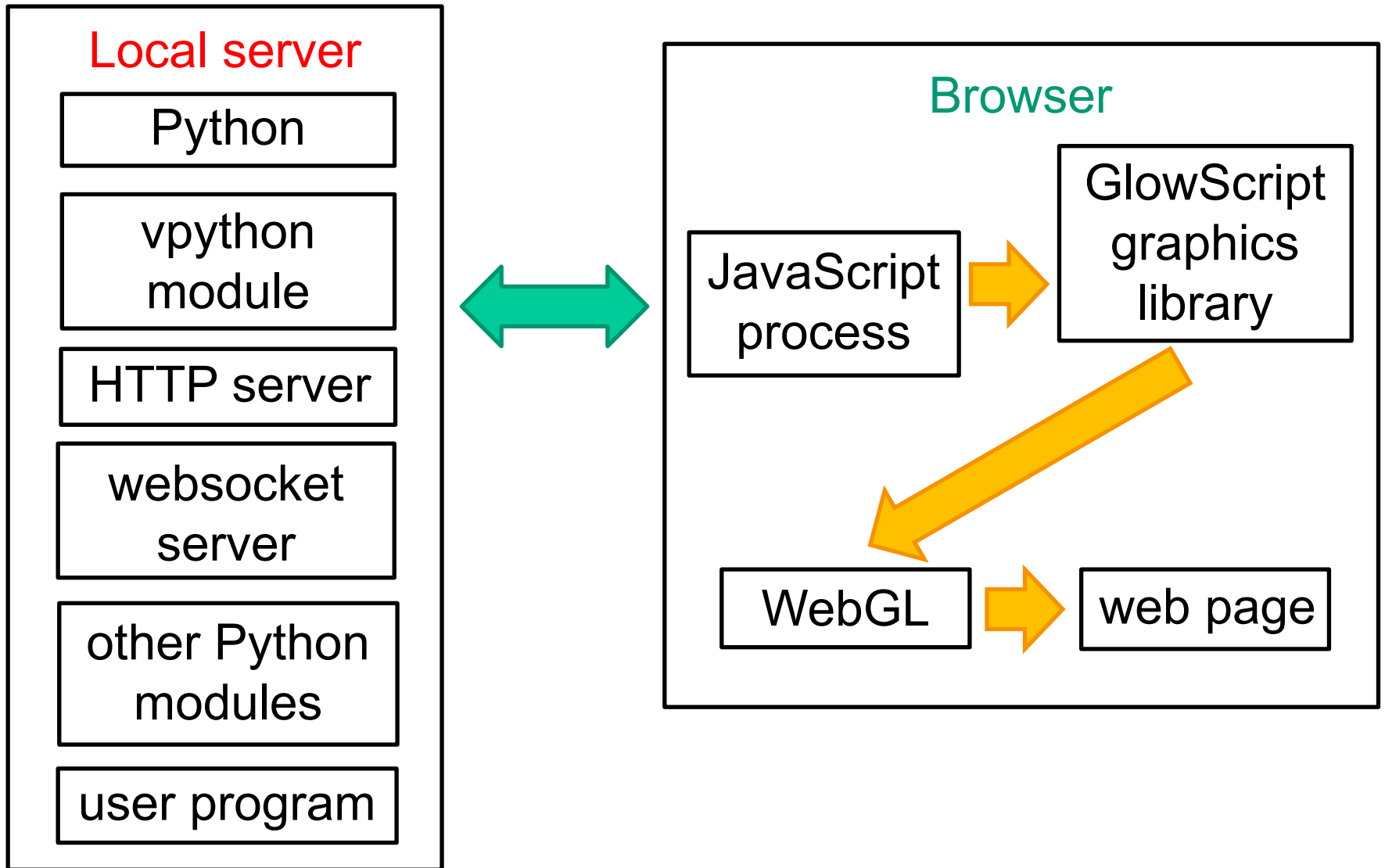
- A complex program can run in multiple environments
- A simple program
 - Well-designed defaults
 - Vector computations
 - 3D animations as side effects of computations
- Can embed in web pages

Web VPython

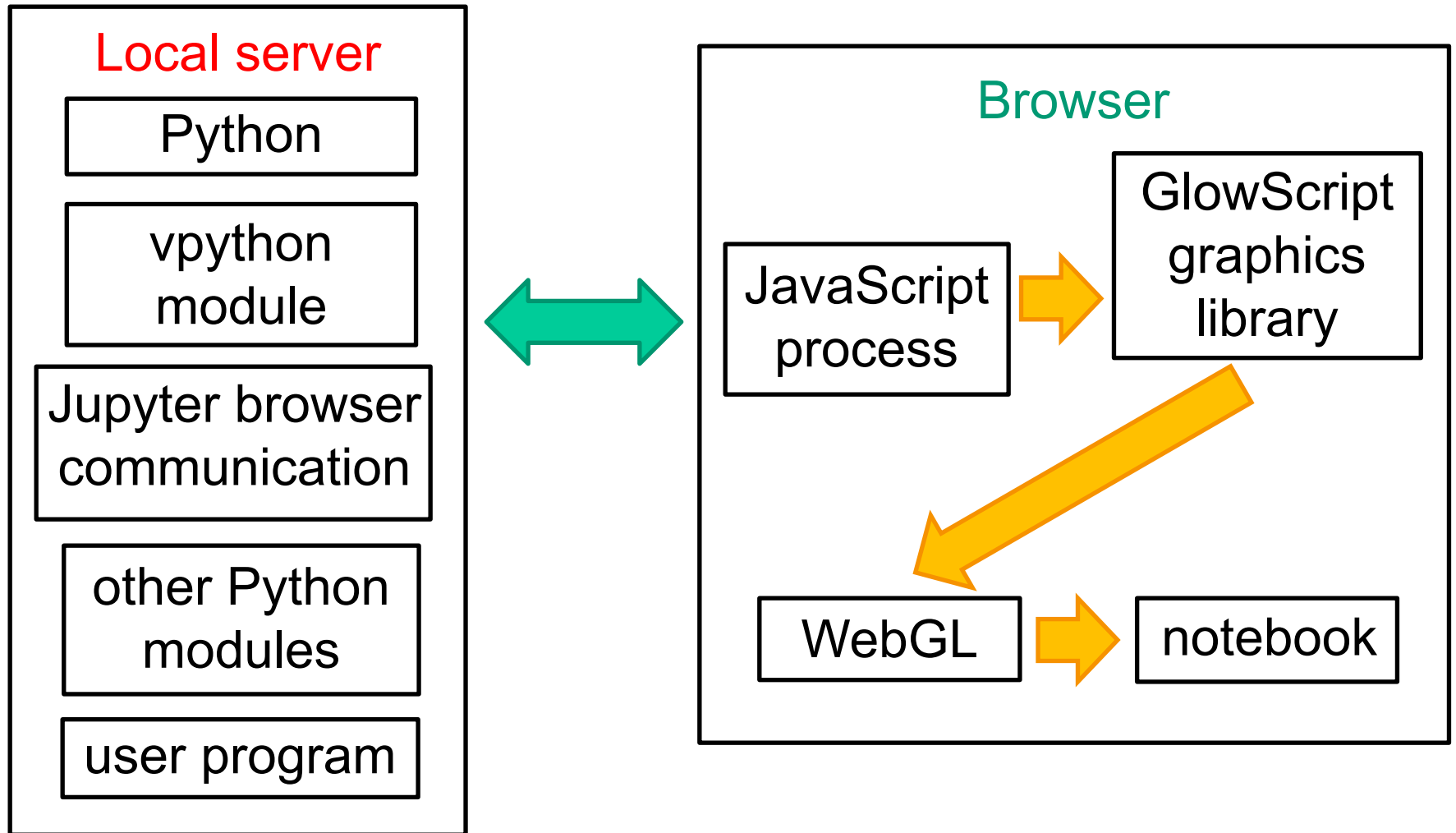


This architecture is also used by trinket.io

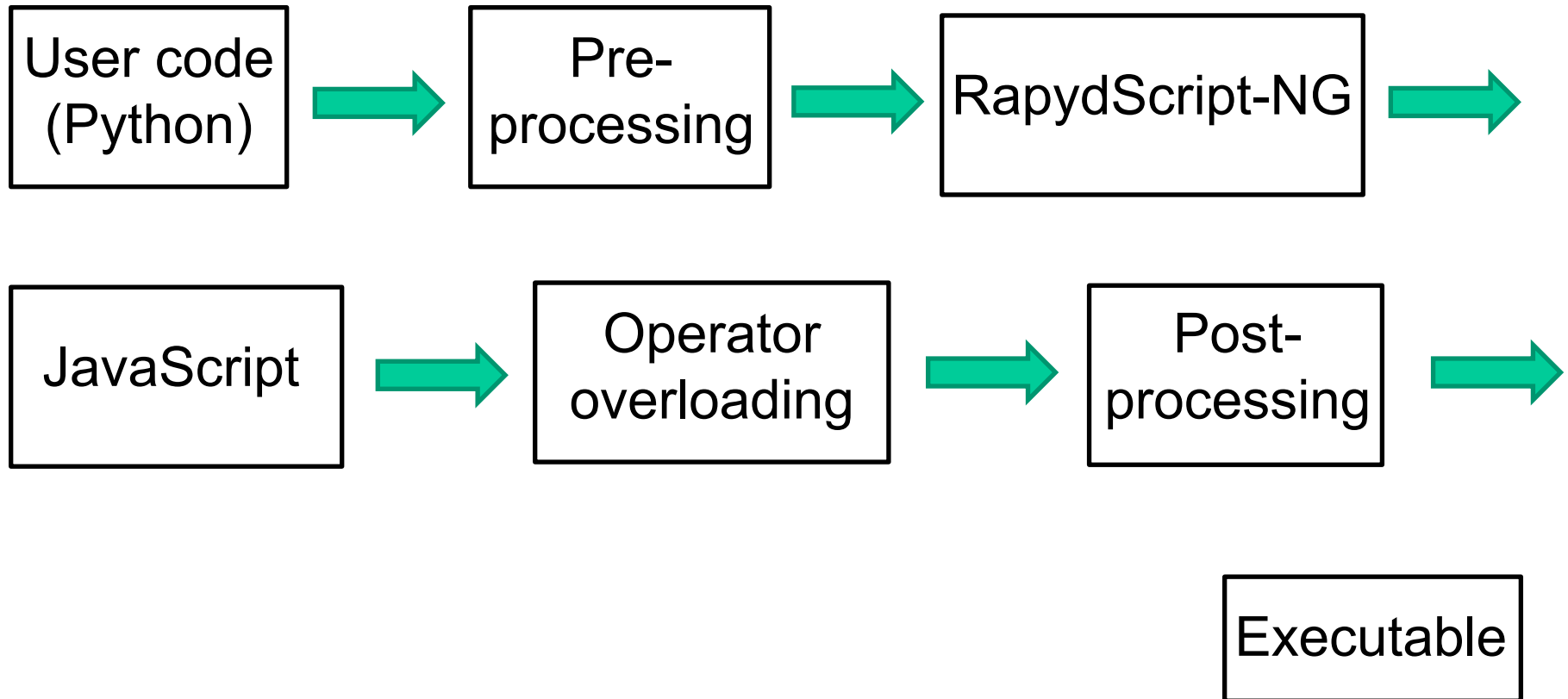
VPython in Python Installations



VPython with Jupyter Notebook



Web VPython: Compilation Details



Operator Overloading: How Vector Addition Works

- Using the PaperScript library with the Acorn parser of JavaScript, convert

`a + b` => `a['+'](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