Pyodide: scientific Python compiled in WebAssembly

Roman Yurchak

FOSDEM 2019

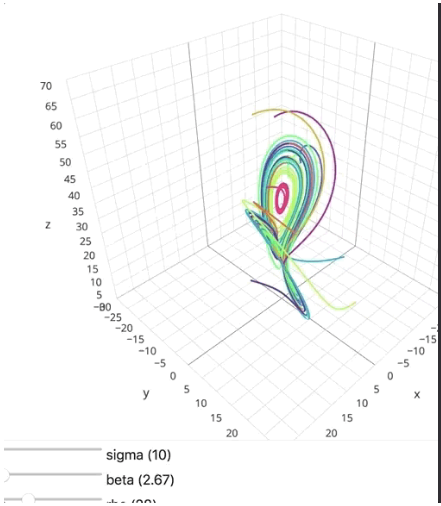
Iodide

An interactive programming environment for scientists in the browser

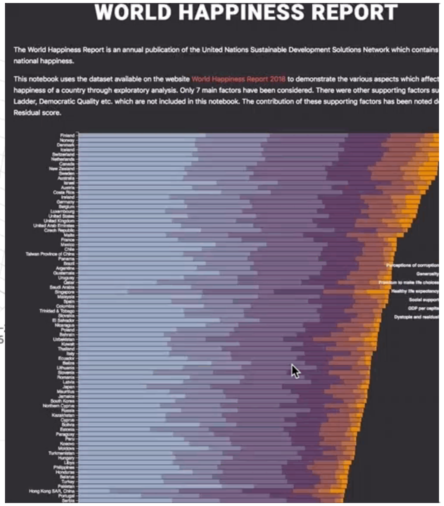
iodide.io

53 I^- Iodide-α 126.90

Examples



Lorenz Attractor

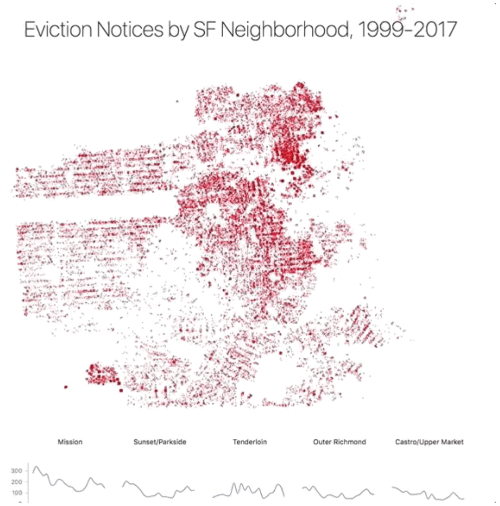


WORLD HAPPINESS REPORT

The World Happiness Report is an annual publication of the United Nations Sustainable Development Solutions Network which contains national happiness.

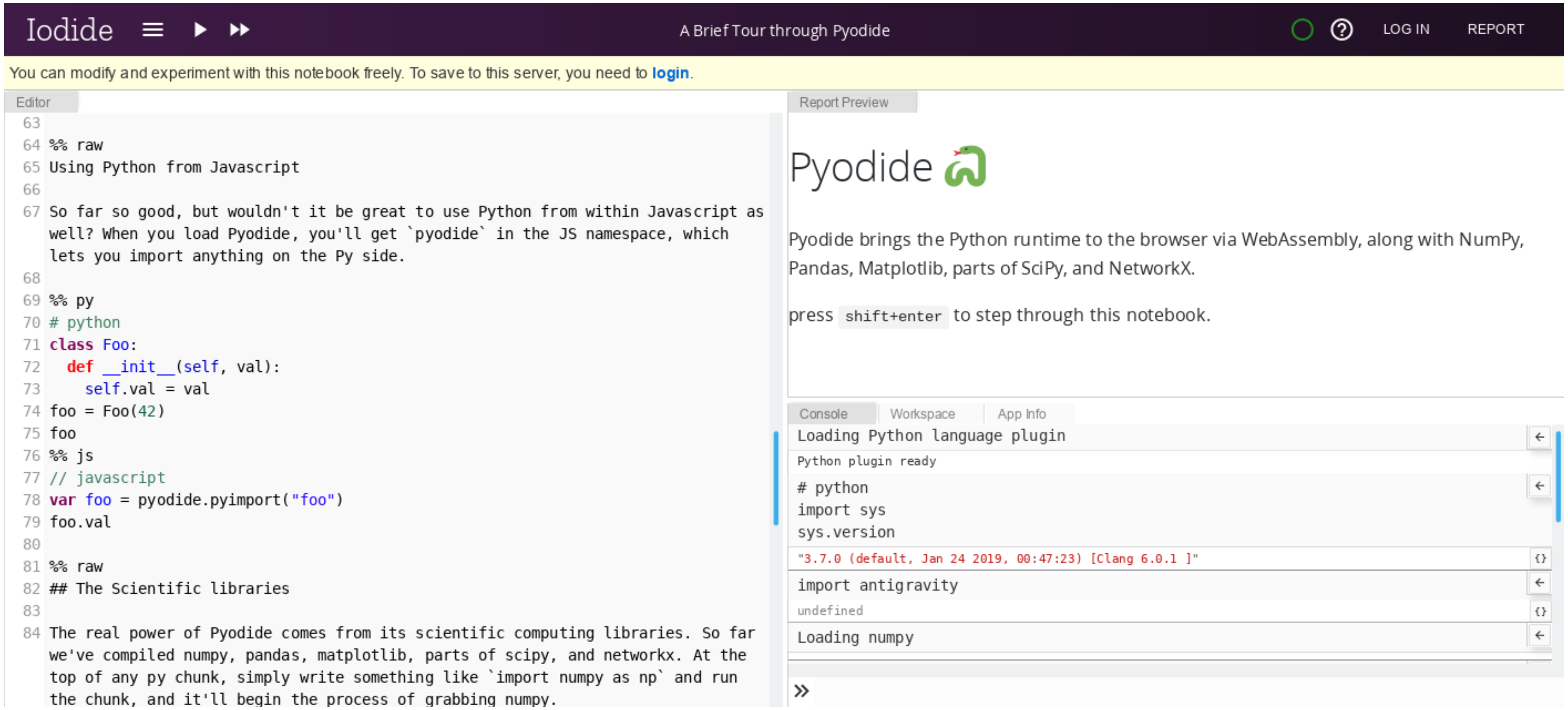
This notebook uses the dataset available on the website World Happiness Report 2018 to demonstrate the various aspects which affect happiness of a country through exploratory analysis. Only 7 main factors have been considered. There were other supporting factors su Ladder, Democratic Quality etc. which are not included in this notebook. The contribution of these supporting factors has been noted d Residual score.

World Happiness Report



Eviction Notices in SF

Iodide overview



You can modify and experiment with this notebook freely. To save to this server, you need to login.

```
%% raw
Using Python from Javascript

So far so good, but wouldn't it be great to use Python from within Javascript as
well? When you load Pyodide, you'll get `pyodide` in the JS namespace, which
lets you import anything on the Py side.

%% py
# python
class Foo:
  def __init__(self, val):
    self.val = val
foo = Foo(42)
foo
%% js
// javascript
var foo = pyodide.pyimport("foo")
foo.val

%% raw
## The Scientific libraries

The real power of Pyodide comes from its scientific computing libraries. So far
we've compiled numpy, pandas, matplotlib, parts of scipy, and networkx. At the
top of any py chunk, simply write something like `import numpy as np` and run
the chunk, and it'll begin the process of grabbing numpy.
```

Pyodide

Pyodide brings the Python runtime to the browser via WebAssembly, along with NumPy, Pandas, Matplotlib, parts of SciPy, and NetworkX.

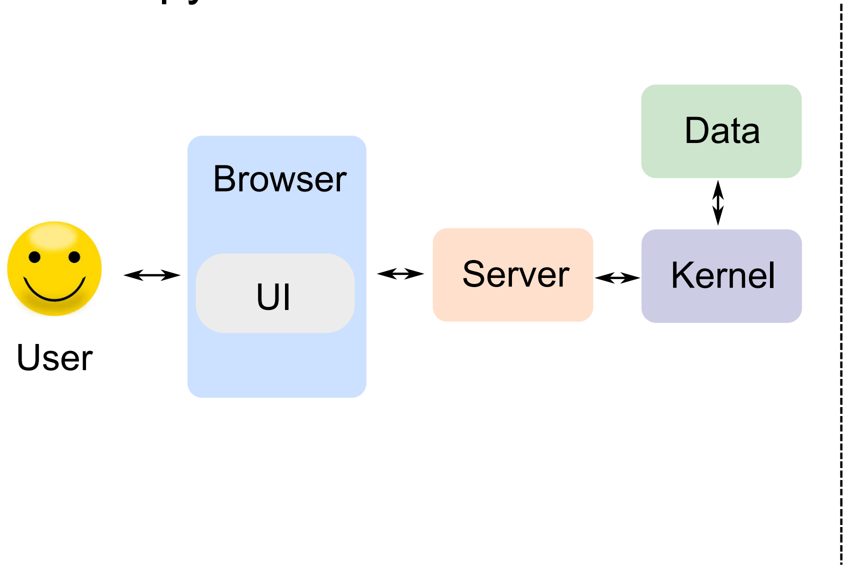
press `shift+enter` to step through this notebook.

```
Loading Python language plugin
Python plugin ready
# python
import sys
sys.version
"3.7.0 (default, Jan 24 2019, 00:47:23) [Clang 6.0.1 ]"
import antigravity
undefined
Loading numpy
```

iodide.io

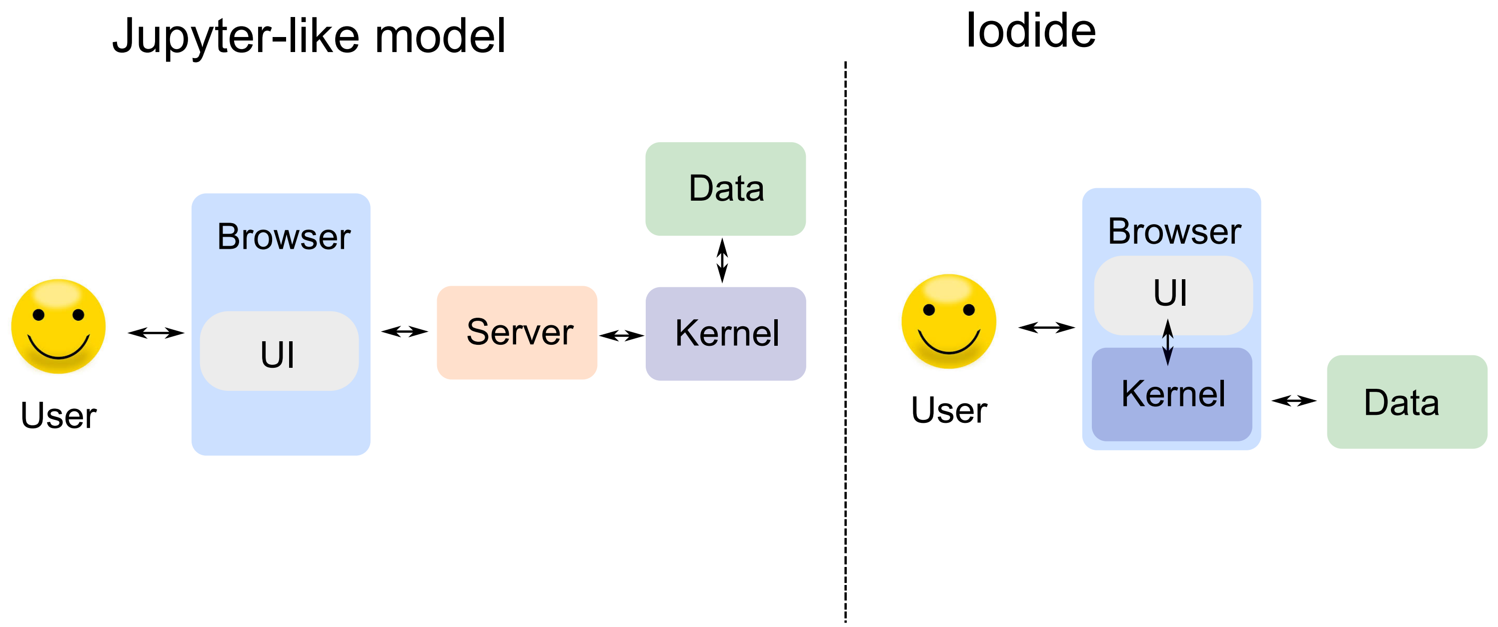
Architecture

Jupyter-like model



Adapted from:
jupyter.readthedocs.io/en/latest/architecture/how_jupyter_ipython_work.html#notebooks

Architecture



Adapted from:
jupyter.readthedocs.io/en/latest/architecture/how_jupyter_ipython_work.html#notebooks

Sharing of notebooks

Jupyter like model

Local

Install conda, Jupyter, then
project-specific dependencies

Remote

Deploy in a container (binder etc.)

Sharing of notebooks

Jupyter like model	Iodide model
Local	**Local**
Install conda, Jupyter, then project-specific dependencies	Deploy to a static webserver Just open it in your browser
Remote	**Remote**
Deploy in a container (binder etc.)	Share a single file containing data, report, code and dependencies Just open it in your browser

Pyodide

Python scientific stack, compiled to WebAssembly

- created by Michael Droettboom
- language plugin for Iodide

CPython interpreter

- numpy, pandas, matplotlib

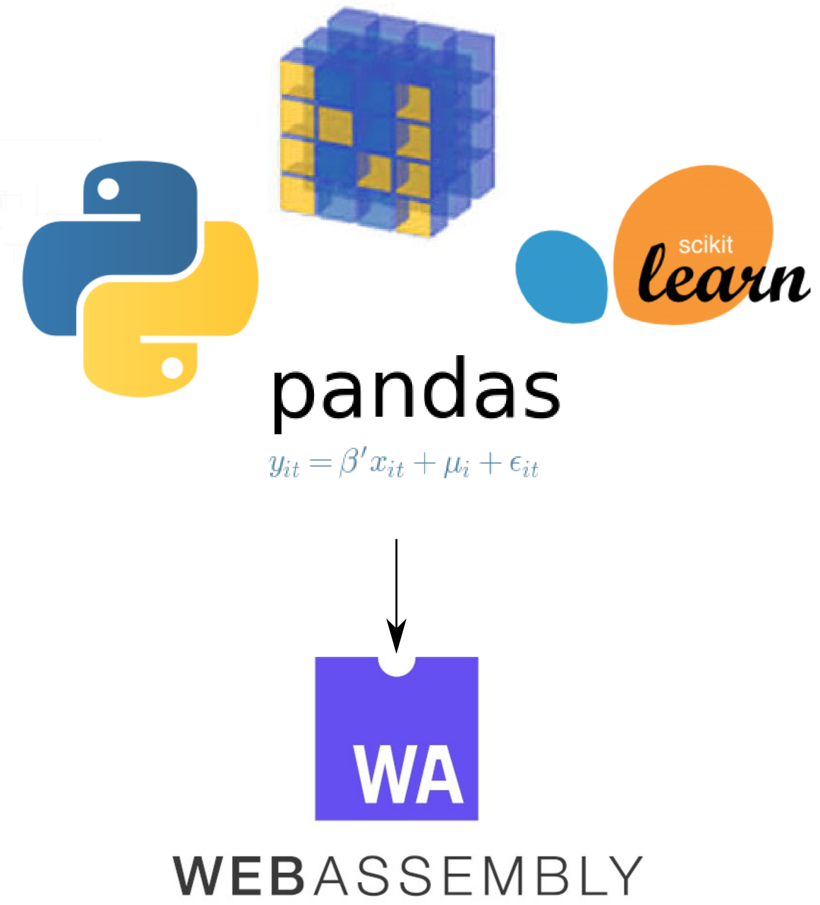
WebAssembly

- A fast way to run compiled code in the browser

Related projects

- PyPy.js, brython, RustPython

github.com/iodide-project/pyodide

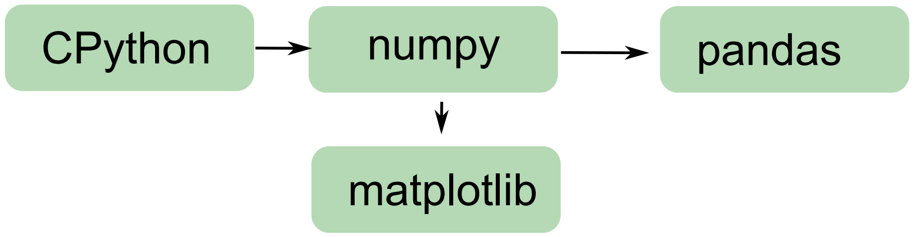


Pyodide example

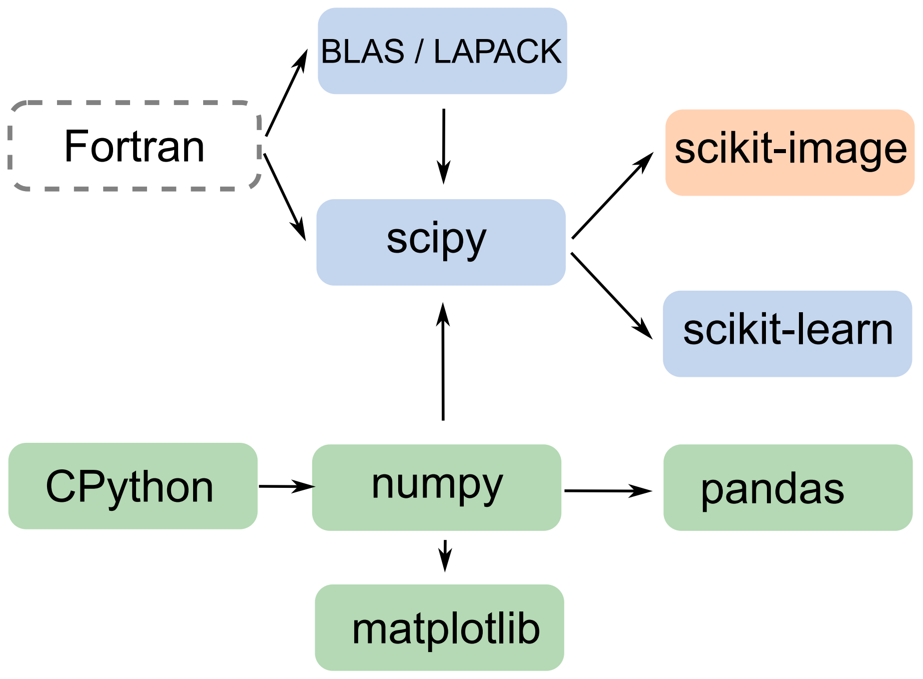
```
<html>
  <head><meta charset="utf-8"/></head>

  <body>
    <script src="http://static.r0h.eu:59171/pyodide.js">
    </script>

    <script>
      languagePluginLoader.then(() => {
          pyodide.loadPackage(['numpy']).then(() => {
              pyodide.runPython(`
                  import numpy as np

                  x = np.random.rand(100)
                  y = x.sum()`
              );

              var y = pyodide.pyimport('y');
              console.log(y);
      });});
    </script>
  </body>
</html>
```

Supported packages

🟩 supported
🟦 experimental
🟧 planned

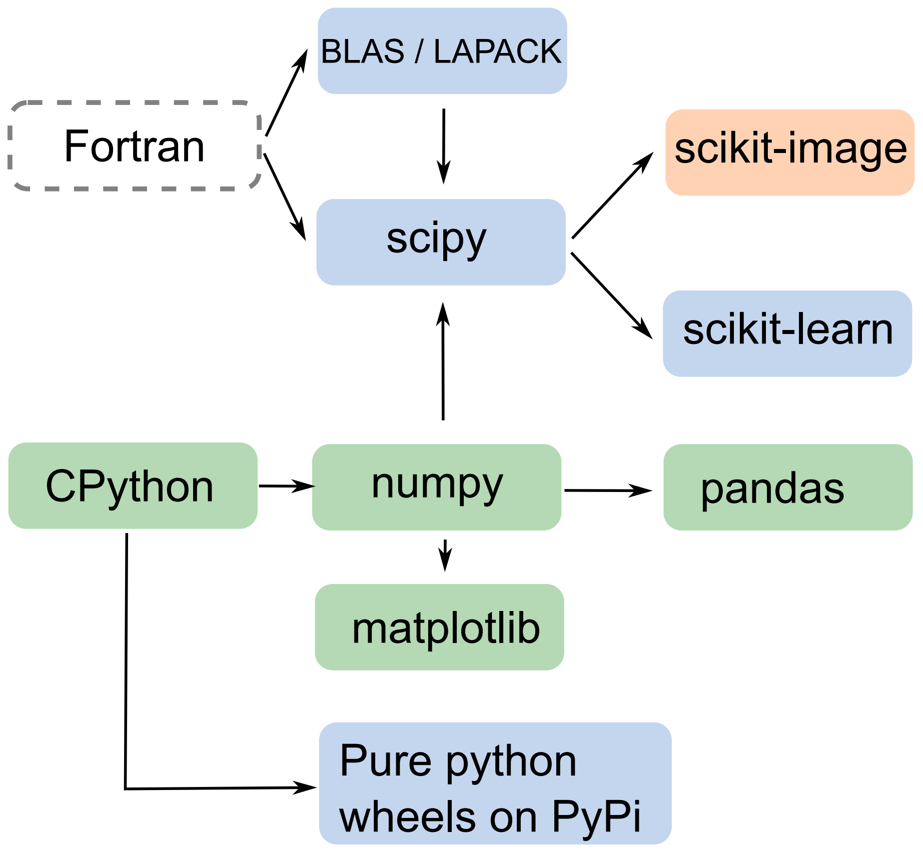


Supported packages



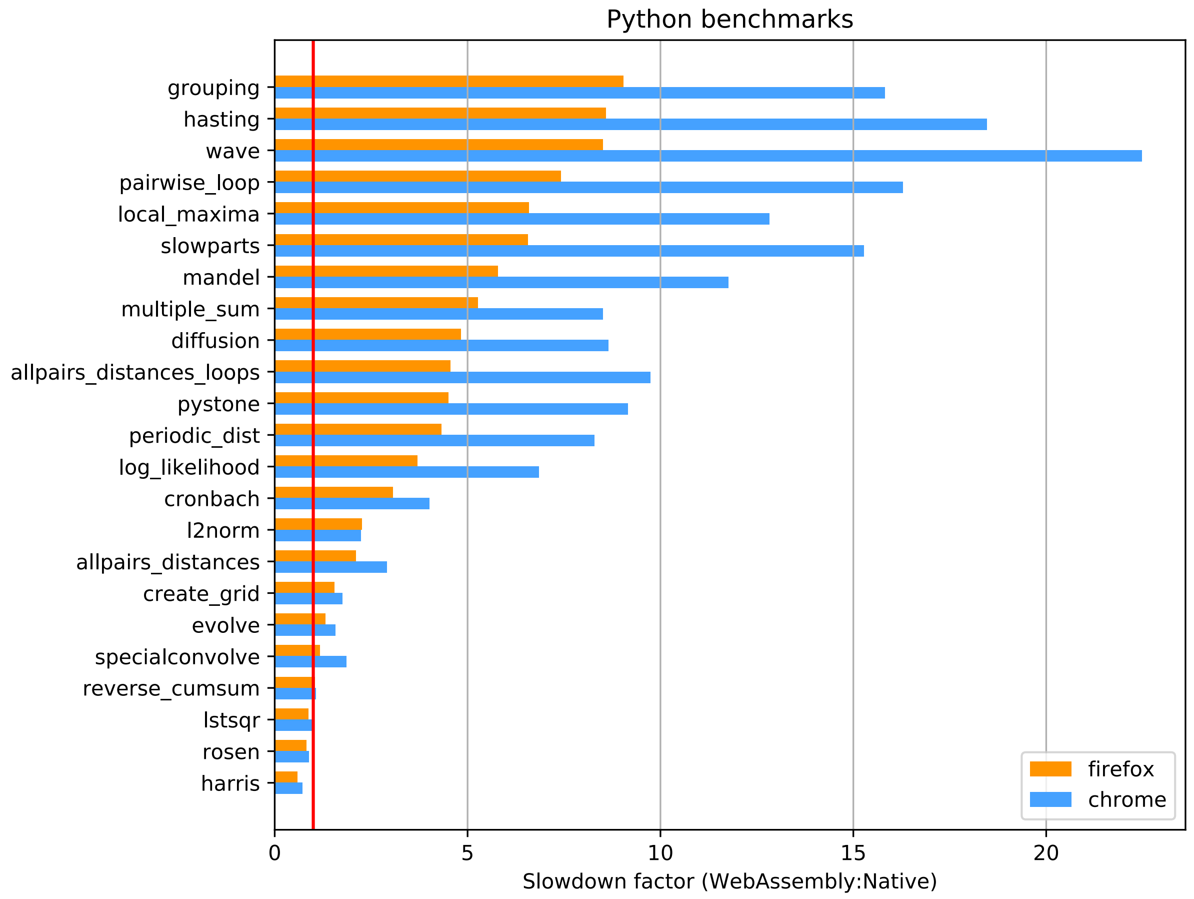
🟩 supported
🟦 experimental
🟧 planned

Supported packages



🟩 supported
🟦 experimental
🟧 planned

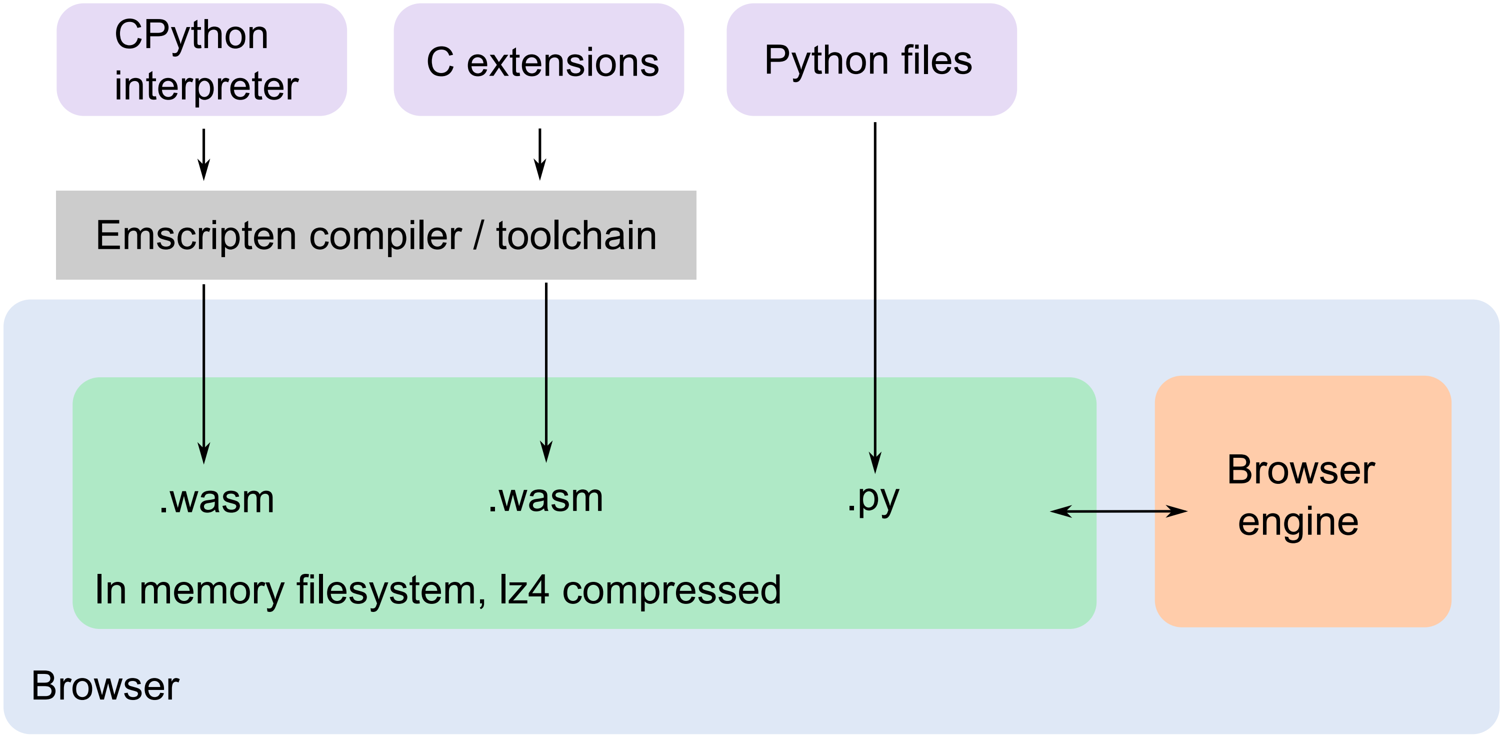
Performance



Firefox: 4-8 slower for pure Python, 1-2 times slower for C-ext. Ideal scaling with the number of users.

github.com/iodide-project/pyodide/tree/master/benchmark

Build process



emscripten.org

emscripten

System calls

For example,

- ↓ `os.open` in Python
- ↓ CPython: call `os_open_impl` C function

System calls

For example,

- ↓ `os.open` in Python
- ↓ CPython: call `os_open_impl` C function

Linux

- ↓ `open` system call to `glibc`
- ↓ Linux kernel

System calls

For example,

- ↓ `os.open` in Python
- ↓ CPython: call `os_open_impl` C function

Linux

- ↓ `open` system call to `glibc`
- ↓ Linux kernel

Emscripten / WebAssembly

- ↓ Emscripten
- ↓ system call to `musl` libc
- ↓ WebAssembly engine

System calls (sometimes)

For example,

- ↓ `os.statvfs` in Python (disk space usage)
- ↓ CPython: call `os_statvfs_impl` C function

Linux

- ↓ `statvfs` system call to `glibc`
- ↓ Linux kernel

Emscripten / WebAssembly

- ↓ Emscripten : not implemented; return "safe and sane values"
- ✗ system call to `musl` libc
- ✗ WebAssembly engine

Most system calls work, but there are some edge cases.

What doesn't work

Difficult

- network sockets
- multiprocessing
- host filesystem access

Should work someday

- threads
- async

Testing

Pytest is supported: test collection and execution in the browser

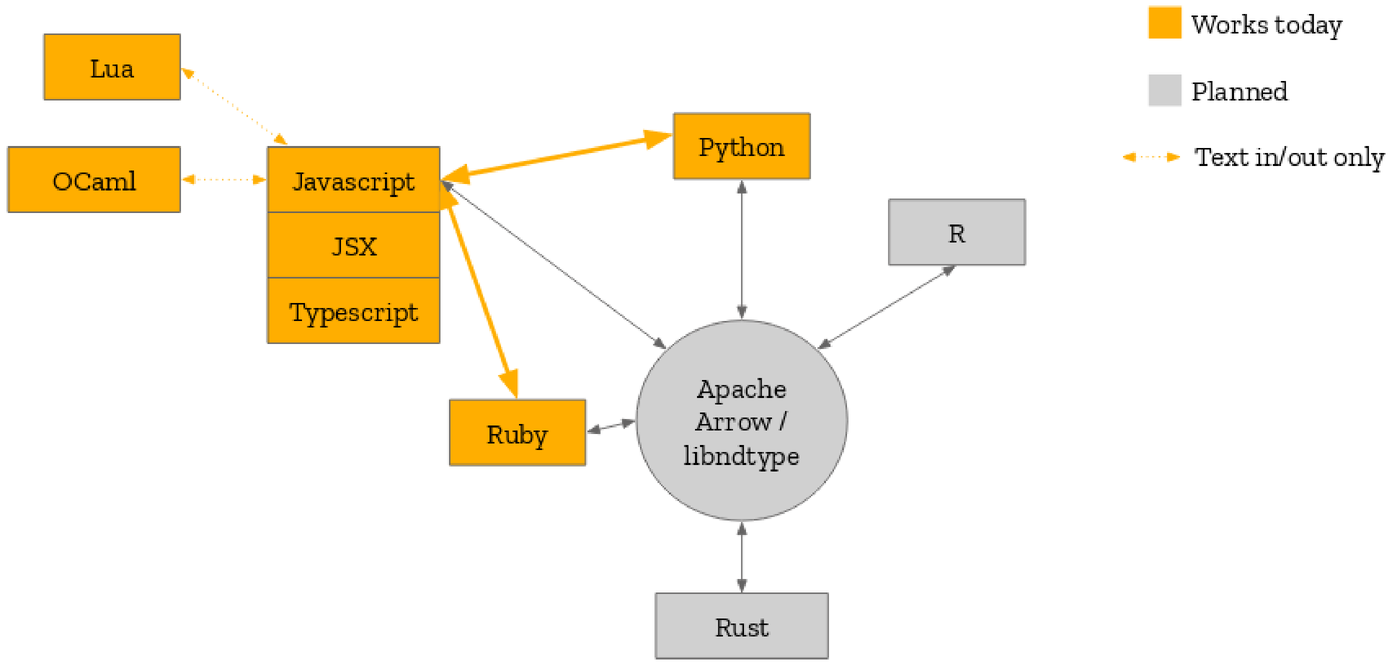
Testing

Pytest is supported: test collection and execution in the browser

Test suites

- CPython: 380 test files / 497 pass (increasing, but some will never pass due to WebAssembly environment)
- numpy: 3145 passed, 42 failed (+ some collection failures), 47 skipped
- scikit-learn: WIP, looks promising. Some remaining issues with Fortran / LAPACK calls in scipy.

Planned language interoperability



Future work

- increase the percentage of passing tests
- dynamic linking of BLAS/LAPACK in scipy
    - possible in Emscripten 1.38.22 thanks to Kirill Smelkov
- optimize download sizes
- threading and async support
- more packages

Contributors welcome!

Application: in-browser data analytics

- challenges of multi-user notebooks deployment
- running notebooks on the edge with uncertain/limited connectivity

- Iodide and Pyodide integrated into the OfficeJS apps store
    - online / offline usage, synchronization in Dropbox etc

nexedi

Development team

Brendan Colloran
Hamilton Ulmer
William Lachance
Michael Droettboom
Teon Brooks
...

Thank you!

Questions?

github.com/iodide-project/pyodide @RomanYurchak