PyPy ~~1.2~~ 1.3: Status and News

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Outline

- PyPy 1.3: what's new and status update
- Overview of the JIT
- `cpyext`: load CPython extensions in PyPy!

Part 0: What is PyPy? :-)

- Python interpreter written in Python
- Framework for developing dynamic languages
- etc. etc.

- From the user point of view
- An alternative to CPython
- with more features!

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Part 1

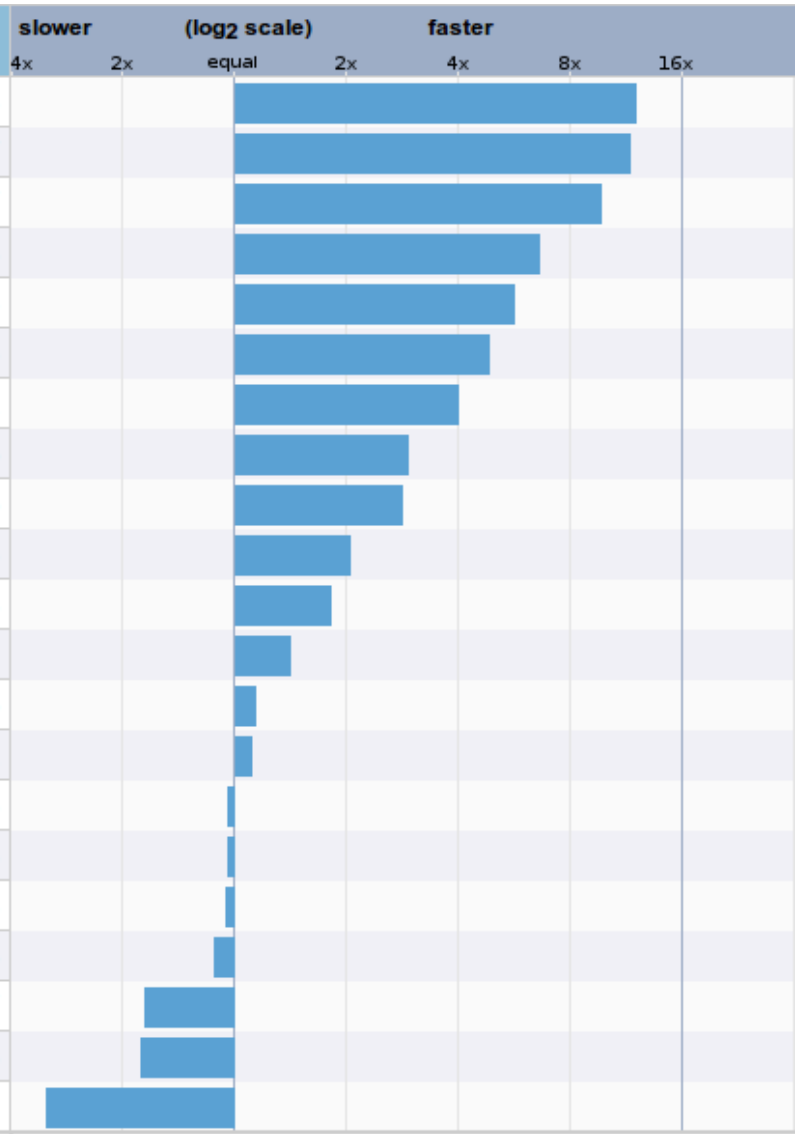
- What's new and status update

What's new in PyPy 1.2, 1.3

- 1.2: released on March 12th, 2010
  - Main theme: speed
  - JIT compiler
  - speed.pypy.org
- 1.3: released on June 26th, 2010
  - Stability: lot of bugfixes, thanks for the feedback :-)
  - More speed!
  - cpyext
- Binaries for Linux, Windows, Mac
- Ubuntu packages

Speed: PyPy vs CPython

Benchmark	Time (s)	std dev	Current change	Trend	Times
richards	0.0246	0.0018	0.32%	-0.23%	12.04
spectral-norm	0.0417	0.0060	-4.43%	-3.90%	11.57
chaos	0.0426	0.0327	4.59%	1.31%	9.77
nbody_modified	0.0810	0.0086	2.48%	0.44%	6.63
float	0.0895	0.0285	-1.83%	-2.37%	5.64
fannkuch	0.3754	0.0122	1.64%	0.60%	4.86
twisted_iteration	0.0329	0.0003	0.10%	-0.64%	4.02
telco	0.3382	0.0155	-0.41%	-1.13%	2.95
django	0.2834	0.0071	-0.48%	-1.05%	2.85
spitfire_cstringio	4.1262	0.1360	-7.40%	-1.18%	2.06
twisted_pb	0.0313	0.0003	-0.67%	-2.43%	1.83
twisted_names	0.0063	0.0000	-0.68%	-1.19%	1.41
html5lib	10.1353	1.5026	2.37%	3.04%	1.15
twisted_web	0.1008	0.0079	-0.39%	-1.04%	1.12
rietveld	0.4946	0.2217	-0.87%	0.21%	0.96
spitfire	7.1760	0.1540	-0.82%	2.35%	0.96
ai	0.4504	0.0078	-3.11%	1.08%	0.94
meteor-contest	0.3509	0.0135	-2.62%	-2.47%	0.88
twisted_tcp	1.6573	0.0176	-2.88%	-1.52%	0.57
slowspitfire	1.2217	0.1532	-7.55%	-0.77%	0.56
spambayes	0.8845	0.0646	-3.65%	-0.24%	0.31



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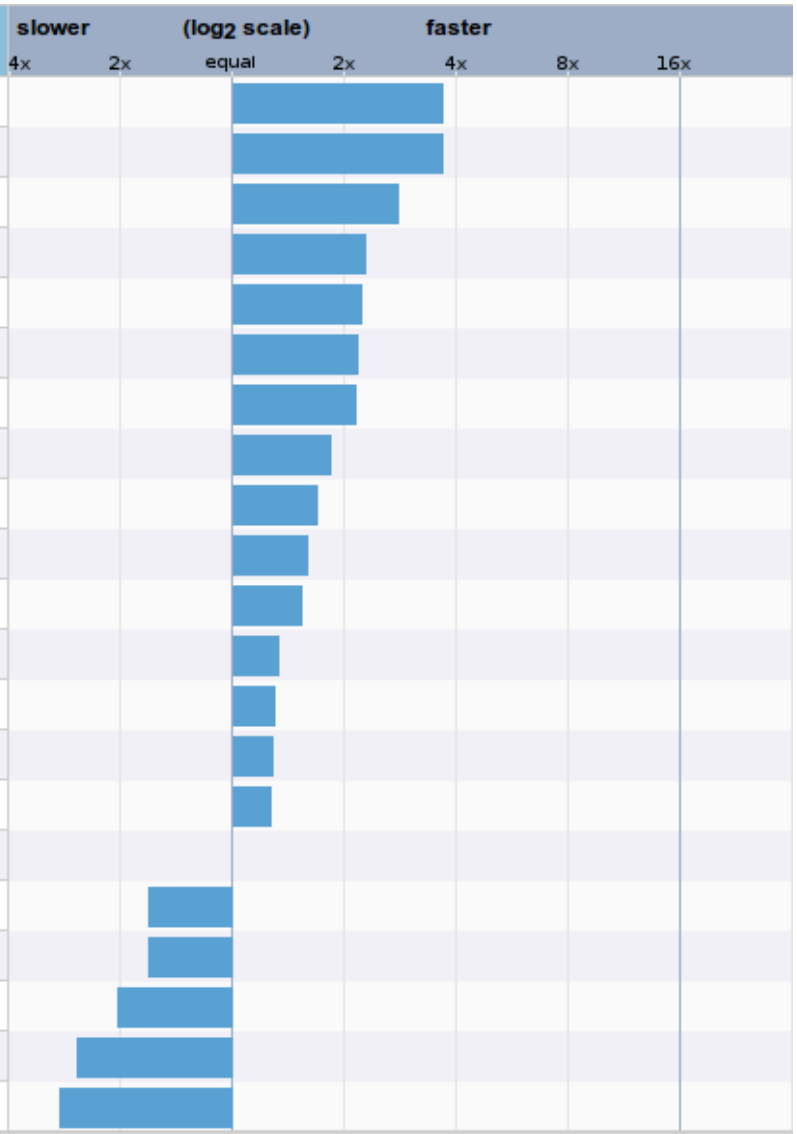

What works on PyPy

- Pure Python modules should Just Work (TM)
  - django trunk
  - twisted, nevow
  - pylons
  - bittorrent
  - ...
- lot of standard modules
  - *__builtin__ __pypy__ _codecs _lsprof _minimal_curses _random _rawffi _socket _sre _weakref bz2 cStringIO crypt errno exceptions fcntl gc itertools marshal math md5 mmap operator parser posix pyexpat select sha signal struct symbol sys termios thread time token unicodedata zipimport zlib*
  - *array binascii cPickle cmath collections ctypes datetime functools grp md5 pwd pyexpat sha sqlite3 syslog*
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What does not work on PyPy

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  - ... unless they don't :-)
- Programs that rely on CPython-specific behavior
  - refcounting: `open('xxx', 'w').write('stuff')`
  - non-string keys in dict of types (try it!)
  - exact naming of a list comprehension variable
  - exact message matching in exception catching code
  - ...
- Extension modules
  - try cpyext!

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Speed: Demo

- Django application
- Mandelbrot fractal
  - fished randomly on the net :-)
- Run both on CPython and PyPy
  - django trunk!

Mandelbrot demo

- Works purely on PyPy
- Not always the case
  - missing extension modules (cpyext mitigates the problem)
  - libraries that rely on CPython details
  - ...
- clear performance-critical part

CPython and PyPy side by side

- CPython: runs the main application
- PyPy: subprocess, runs only the hotspots
- How do they communicate?
- execnet
  - **The Ring of Python**, Holger Krekel, 9:45
  - oups, too late :-)

Rendering (1)

Mandelbrot

```
def render(request):
    w = int(request.GET.get('w', 320))
    h = int(request.GET.get('h', 240))

    from py_mandel import mandelbrot
    img = mandelbrot(w, h)

    return HttpResponse(img, content_type="image/bmp")
```

Rendering (2)

Mandelbrot on PyPy

```
def pypy_render(request):
    w = int(request.GET.get('w', 320))
    h = int(request.GET.get('h', 240))

    channel = pypy.remote_exec("""
        from py_mandel import mandelbrot
        w, h = channel.receive()
        img = mandelbrot(w, h)
        channel.send(img)
    """)
    channel.send((w, h))
    img = channel.receive()

    return HttpResponse(img, content_type="image/bmp")
```

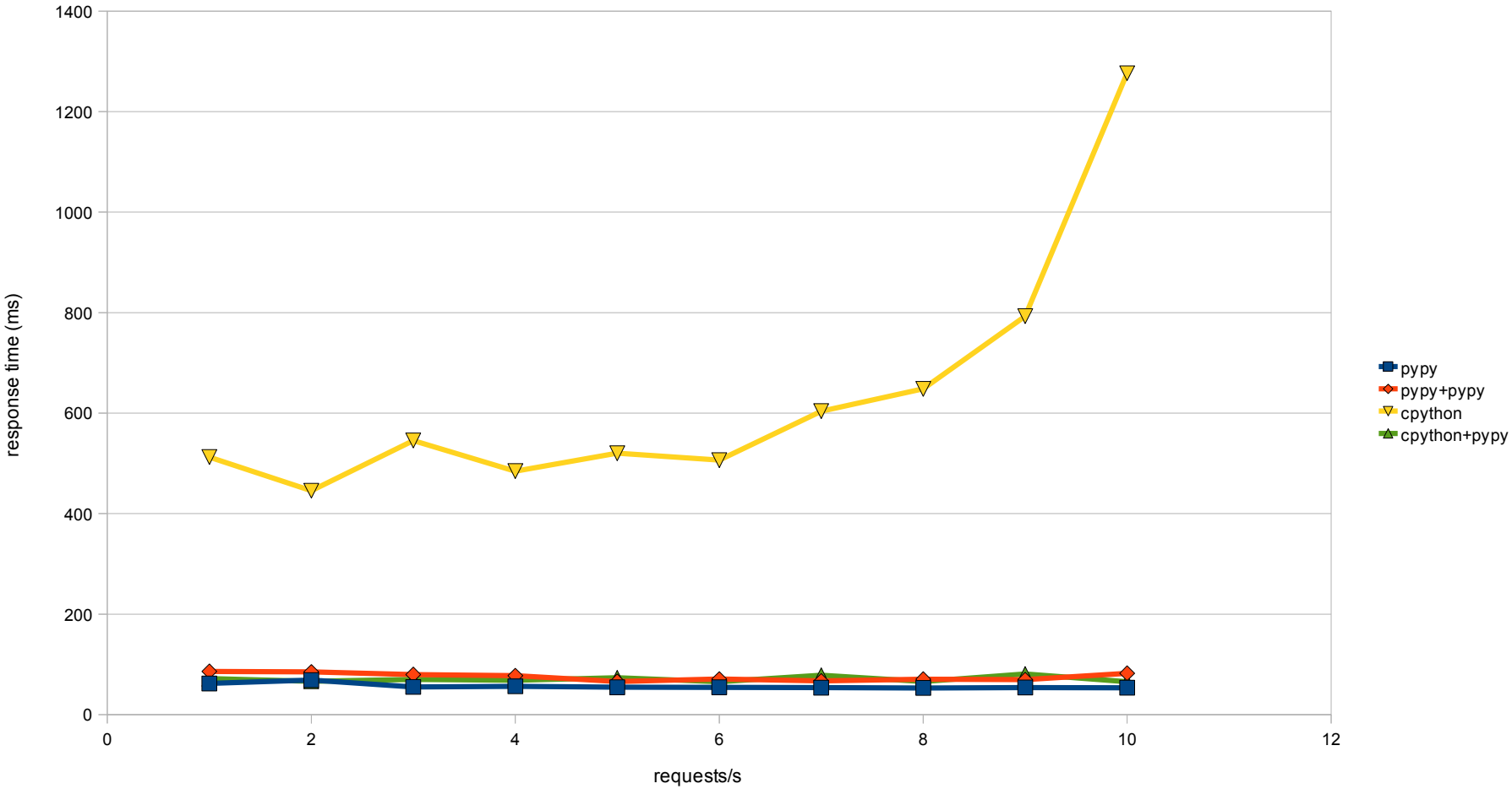
execnet setup

At startup

```
import execnet
mygroup = execnet.Group()
pypy = mygroup.makegateway("popen//python=pypy-c")
pypy.remote_exec("""
    import sys
    import os
    os.chdir("mandelbrot")
    sys.path.insert(0, '')
""")
```

Demo

Benchmarks


1400
1200
1000
800
600
400
200
0
response time (ms)
0
2
4
6
8
10
12
requests/s
pypy
pypy+pypy
cpython
cpython+pypy

Part 2: Just-in-Time compilation

Snakes never crawled so fast

Overview of implementations

- CPython
- Stackless
- Psyco
- Jython
- IronPython
- PyPy (without and with JIT)
- Unladen Swallow

Demo

Features

- it just works
- it may give good speed-ups (better than Psyco)
- it may have a few bugs left (Psyco too)
- it is not a hack (unlike Psyco)
- PyPy also has excellent memory usage
  - half that of CPython for a program using several hunderds MBs

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What is a JIT

- CPython compiles the program source into bytecodes
- without a JIT, the bytecodes are then interpreted
- with a JIT, the bytecodes are further translated to machine code (assembler)

What is a JIT (2)

The translation can be:

- syntactic: translate the whole functions into machine code
  - "the obvious way"
  - e.g. Pyrex/Cython, Unladen Swallow
  - not good performance, or needs tricks
- semantic: translate bits of the function just-in-time
  - only used parts
  - exploit runtime information (e.g. types)
  - Psyco, PyPy

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What is a tracing JIT

- start by interpreting normally
- find loops as they are executed
- turn them into machine code
- 80% of the time is spent in 20% of the code

What is a tracing JIT (history)

- tracing assembler (Dynamo, ~2000)
- tracing Java (~2005)
- tracing JavaScript (~2008)

- PyPy is a "tracing JIT generator"

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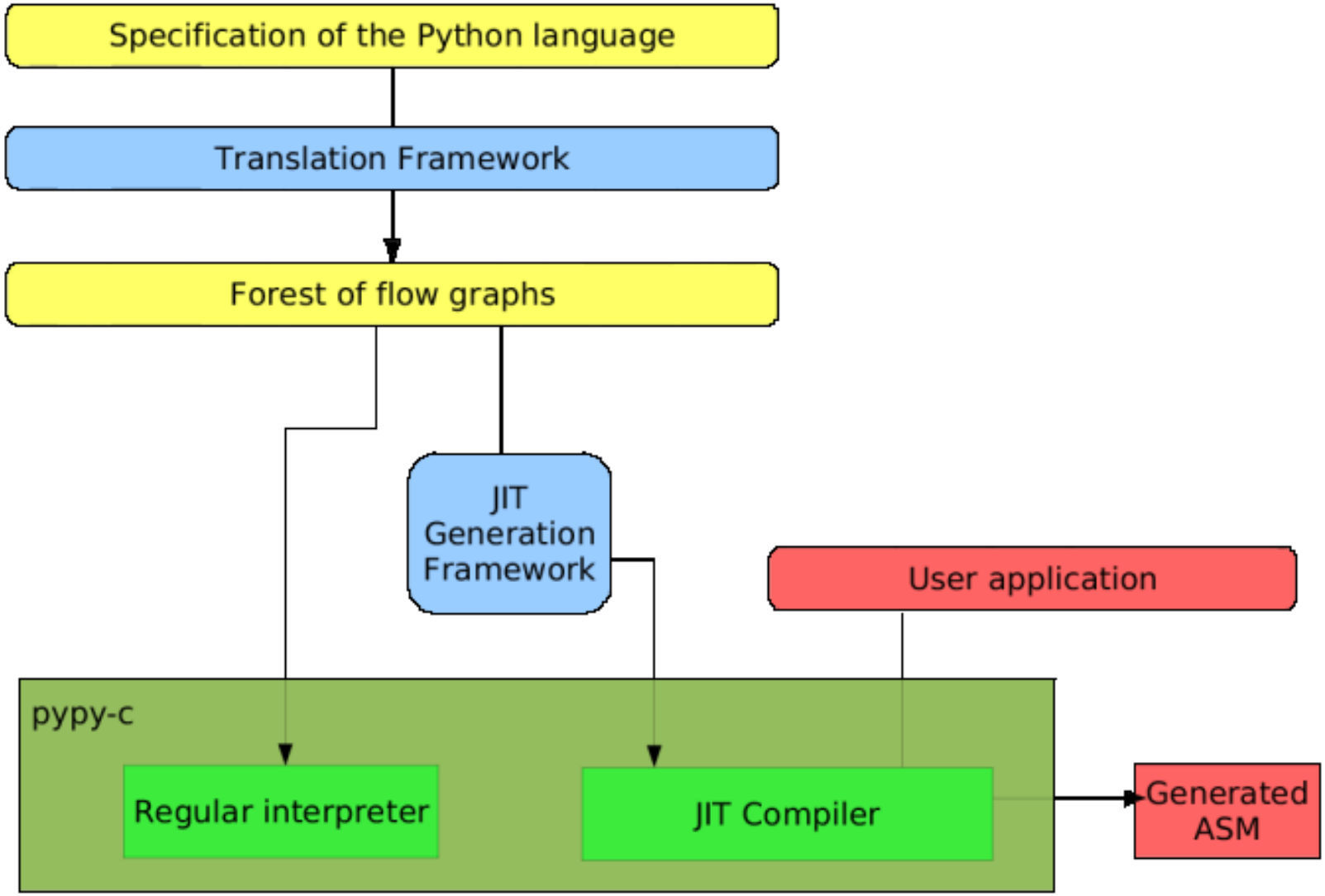
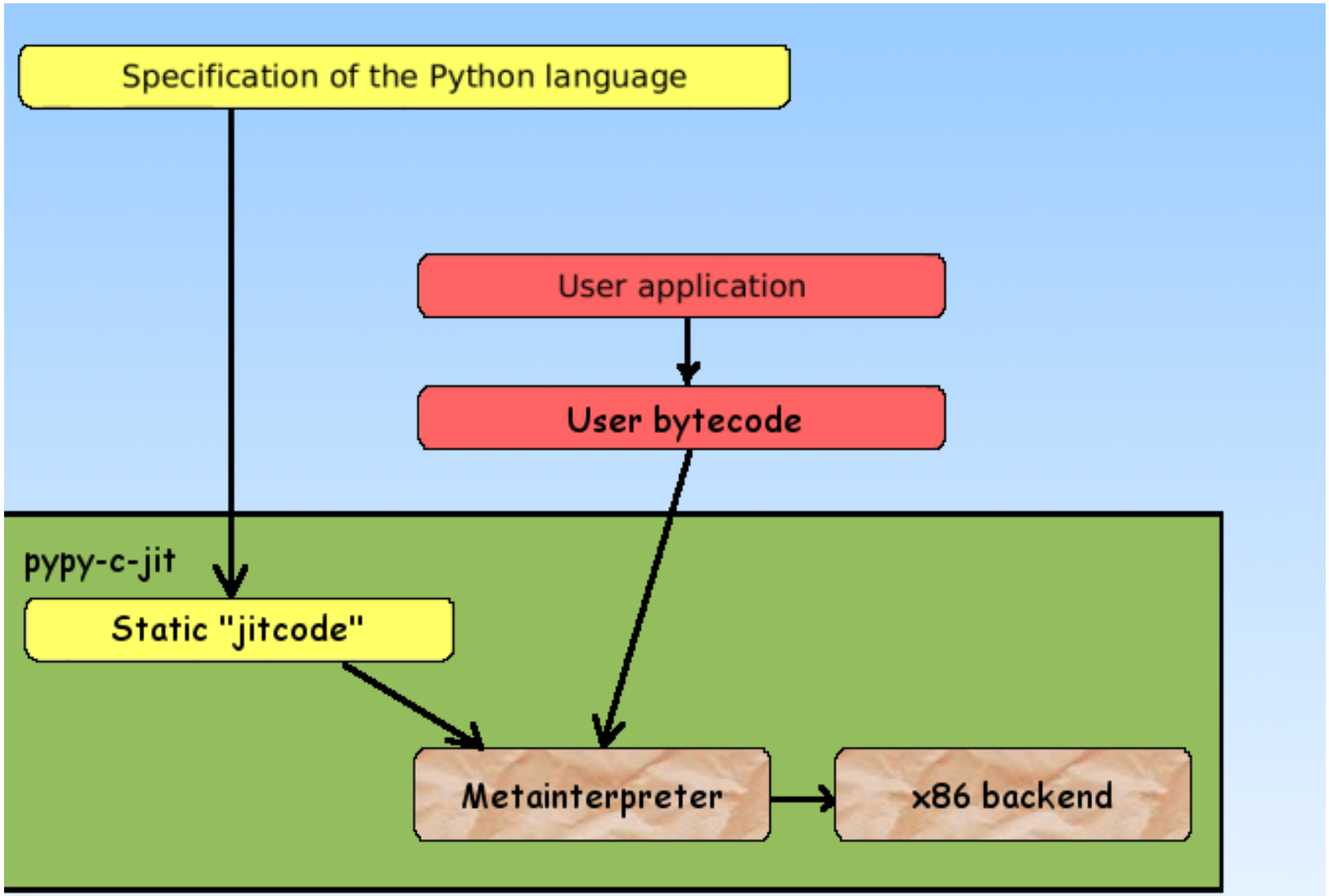
The architecture of PyPy



The architecture of PyPy (2)



Speed of the PyPy JIT

Python programs that are, or are not, nicely handled by the JIT:

- loops, even across many calls, are nicely handled
- loops with very many taken paths are not
  - e.g. Python programs that look like interpreters
  - typical in tracing JITs
- bad support so far for generators and recursion

The optimizations we get

- != optimizations we wrote :-)
- removed frame handling
  - local variables are in CPU registers or on the C stack
  - but `sys._getframe()` works correctly
- "virtuals": temporary objects are not constructed
  - `e = a + b + c + d`
  - and much more complex examples
- attribute and method lookups, etc.

Example

```
def g(a, b):
    if a < 5:          # 2
        return -1
    return a - b       # 3

def f(x):
    total = 0
                       # 1
    for i in range(x):
        d = g(i, x)
        total += d     # 4
```

```
ADD EAX, 1
CMP EAX, EBX
JNL <guard 1>
CMP EAX, 0
JL <guard 2>
MOV ECX, EAX
SUB ECX, EBX
JO <guard 3>
ADD EDX, ECX
JO <guard 4>
JMP
```

Practical results

- fast :-)
- so far, x86-32 only
- relatively easy to maintain (or port to x86-64, etc.)
- reminder: works transparently for any Python code
  - or any language (Prolog JIT :-) at PPDP 2010)
- viable alternative to CPython

Part 3

cpyext

cpyext

- CPython extension modules in PyPy
- `pypy-c setup.py build`
- included in PyPy 1.3
- still beta
- 50% of the CPython API is supported
  - enough for 90% of extension modules

features

- C API written in Python!
- Testable on top of an interpreted py.py
- Written on top of the object space
- Source compatibility
  - PyString_AS_STRING is actually a function call (instead of a macro)

```
@cpython_api([PyObject], Py_ssize_t, error=-1)
def PyDict_Size(space, w_obj):
    return space.int_w(space.len(w_obj))
```

implementation

- It was not supposed to work!
  - different garbage collector
  - no "borrowed reference"
  - all the PyTypeObject slots
- not faster than python code!
- PyObject contains ob_type and ob_refcnt
  - The "abstract object interface" is used.
- Some objects contain more:
  - PyString_AsString() must keep the buffer alive at a fixed location
  - PyTypeObject exposes all its fields

The Reference Counting Issue

- pypy uses a moving garbage collector, starts with static roots to find objects.
- CPython objects don't move, and PyObject* can point to deallocated memory.
- cpyext builds PyObject as proxies to the "real" interpreter objects
- one dictionary lookup each time the boundary is crossed
- More tricks needed for borrowing references
  - The object lifetime is tied to its container.
  - "out of nothing" borrowed references are kept until the end of the current pypy->C call.

supported modules

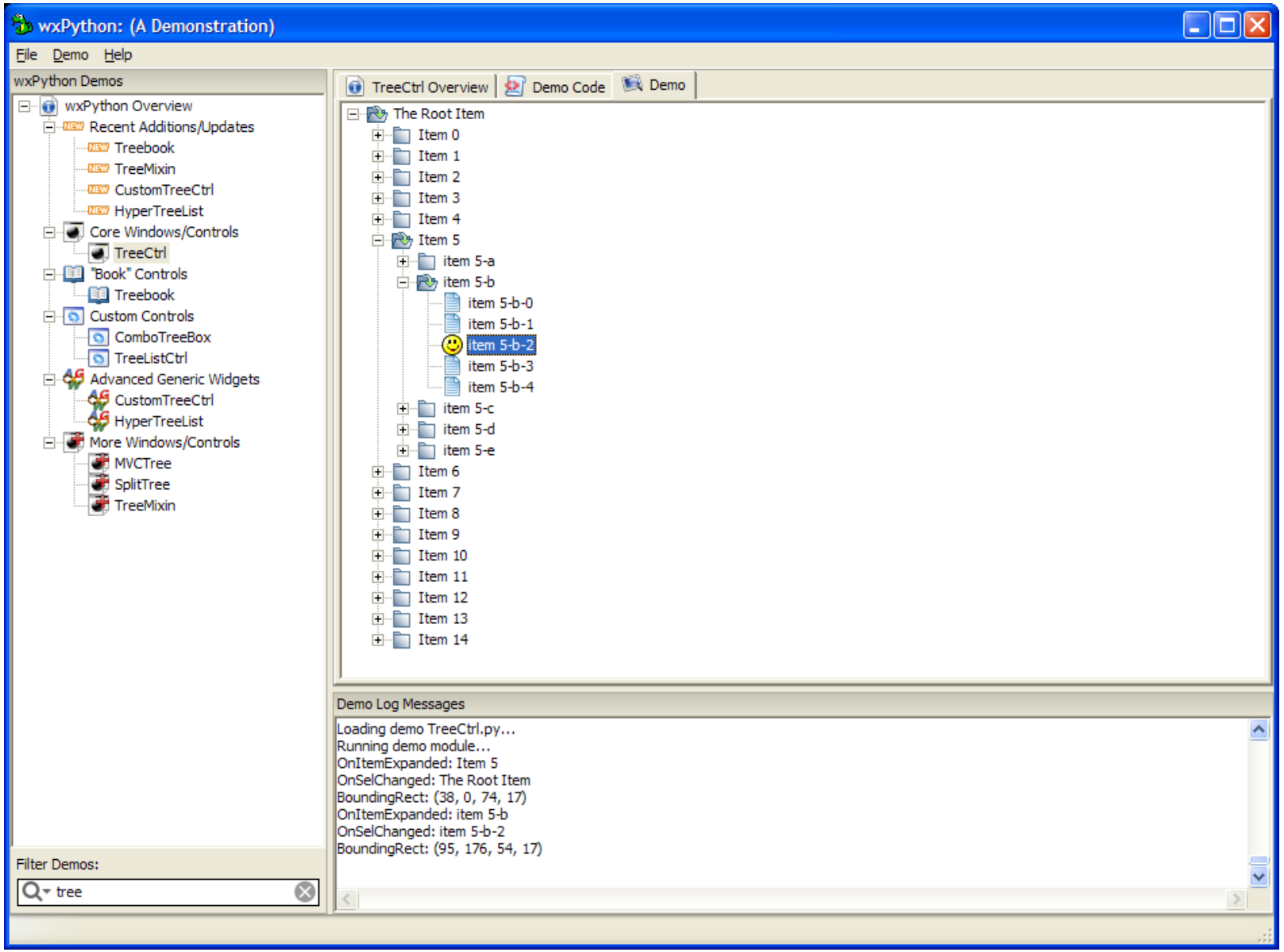
- Known to work (after small patches):
  - wxPython
  - _sre
  - PyCrypto
  - PIL
  - cx_Oracle
  - MySQLdb
  - sqlite

Why your module will crash

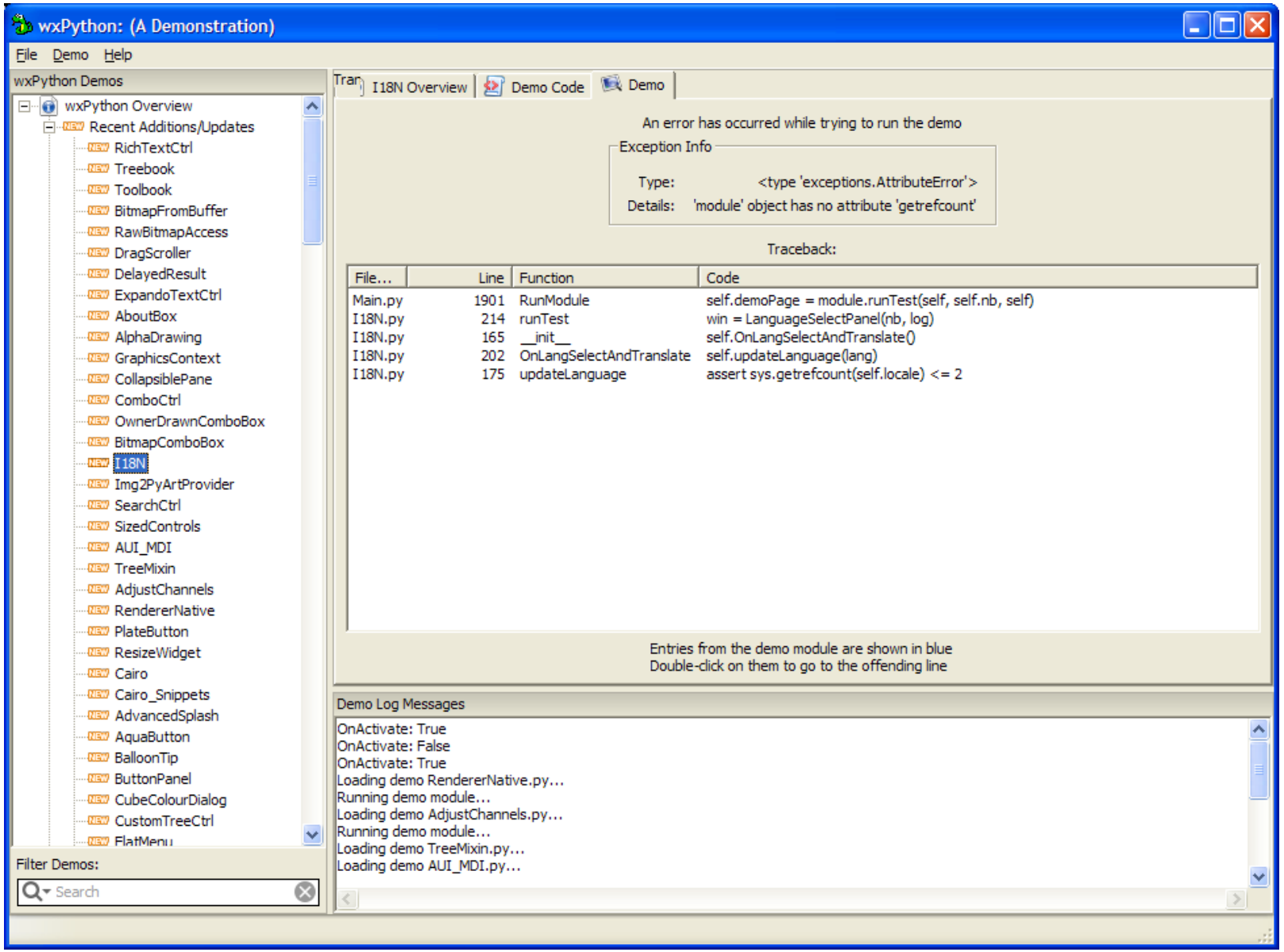
Likely:

```
static PyObject *myException;

void init_foo() {
    myException = PyException_New(...);
    Py_AddModule(m, myException); // steals a reference
}

{
    PyErr_SetString(myException, "message"); // crash
}
```

wxPython on PyPy (1)



wxPython on PyPy (2)



performance (1)

```
from cx_Oracle import connect, STRING
c = connect('scott/tiger@db')
cur = c.cursor()
var = cur.var(STRING)

def f():
    for i in range(10000):
        var.setvalue(0, str(i))
        var.getvalue(0)

python -m timeit -s "from test_oracle import f" "f()"
python2.6:    8.25 msec per loop
pypy-c:      161   msec per loop
pypy-c-jit: 121   msec per loop
```

performance (2)

Compare with:

```
def f():
    for i in range(10000):
        x = str(i)
        y = int(x)
```

```
python2.6:     8.18 msec per loop
pypy-c-jit:    1.22 msec per loop
```

Future developments

- Some care about speed
  - The JIT can help to remove (some of) the overhead
- Fill missing API functions (when needed)
- Better suppport of the PyTypeObject slots
- Think about threads and the GIL
- Think about reference cycles

Contact / Q&A

- Antonio Cuni: at http://merlinux.eu
- Armin Rigo: arigo (at) tunes.org
- Amaury Forgeot d'Arc: amauryfa (at) gmail
- And the #pypy IRC channel on freenode.net!
- Links:
  - PyPy: http://pypy.org/
  - PyPy speed center: http://speed.pypy.org/
  - Blog: http://morepypy.blogspot.com