Unladen Swallow: Fewer coconuts, faster Python

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unladen-swallow@googlegroups.com #unladenswallow on OFTC



Why did Google start this?

- Lots of Python at Google.
 - Python one of Google's three primary languages.
 - Python enables fast development, rapid prototyping.
 - Engineers should use the language they want...
 - ...and it should be fast.

- Biggest user: YouTube
 - YouTube is pure-Python.
 - #2 search site on the Internet, behind google.com.



Goals

- Make Python 5x faster.
- Source-compatible with existing Python code.
- Source-compatible with existing C extension modules.
- Focus on ease of migration.
- Open-source everything, merge back into CPython.
- Baseline requirements:
 - Embeddable in C++ applications.
 - Support existing C extension modules and SWIG.
 - Compatible with all our existing applications.
 - Compatible with our existing infrastructure.
 - As fast, or faster, than CPython.
- Baseline: branch CPython.

Google

Why is Python slow?

```
def add(a, b):
    return a + b
```

- Everything is an object.
- Everything is a method call, eventually.
- Ducktyping means we can't statically predict receiver types.



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Google

Why is Python slow?

```
def foo(x):
   yield len(x)
   yield len(x)
>>> g = foo(range(5))
>>> g.next()
5
>>> len = lambda y: 8
>>> g.next()
8
```



How do you make Python faster?

- CPython today:
 - Stack-based bytecode interpreter.
 - Missed the last 30 years of research.

- Conservative ideas:
 - Computed goto-based interpreter loop.
 - Add new, specialized opcodes.
 - Superinstructions (WPython)

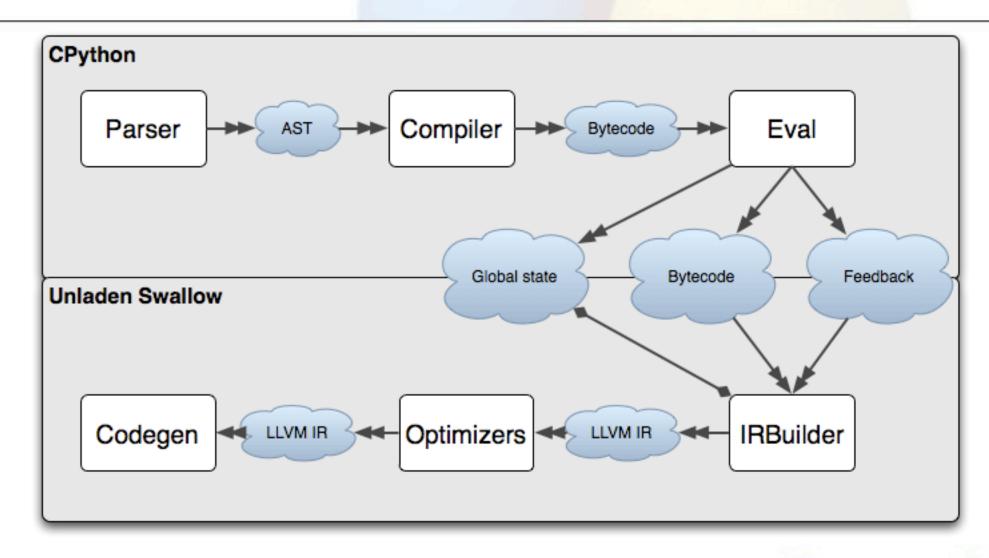


Unladen Swallow

- Unladen Swallow: just-in-time compilation.
 - Preserve C extension compatibility.
 - Use LLVM for code generation, optimization.
 - Use Clang for inlining C functions.
 - Runtime feedback for specialization.
 - Inspired by Self-93, HotSpot, V8, Psyco.



Unladen Swallow





Top-down Inlining Opportunties

```
...len() calls PyObject_Size()
...which looks up x->ob_type->tp_as_sequence->sq_length
...which is NULL, so call PyMapping_Size()
...which looks up x->ob_type->tp_as_mapping->mp_length
...which is a function pointer to dict_length()
...which returns x->ma_used
```



>>> x = dict()

Using Clang and Ilc for Inlining

- Pipeline: C --> LLVM .bc --> C++ API calls
- Inline useful macros:

```
/*** Python/llvm_inline_functions.c ***/
void __attribute__((always_inline))
_PyLlvm_WrapDecref(PyObject *obj)
{
        Py_DECREF(obj);
}
```

Uses a custom single-function inlining pass.



Python Objects: constant(ish)

```
struct PyDictObject {
    Py ssize t ob refcnt;
    PyTypeObject *ob type; -
    Py ssize t ma fill;
    Py ssize t ma used;
};
PyTypeObject PyDict Type = {
    &dict as sequence,
    &dict as mapping,
};
```

Experience with LLVM

- Generally very positive!
- Obstacles overcome:
 - JIT bugs.
 - gdb/oprofile support.
 - Some quadratic behaviour.
- Obstacles remaining:
 - LLVM does not cure cancer.
 - Some optimizations missing.
 - More lurking quadratic behaviour.
 - Python semantics.
- Stop; collaborate; listen.



Measurement & Testing

- Benchmarks representing real-world applications:
 - YouTube hotspots: Spitfire templates.
 - o Libraries: pickling, regular expressions.
 - Apps: 2to3, Django.
 - o Microbenchmarks: GC, IO, string operations.
- Correctness:
 - SWIGed code, extensions used by YouTube.
 - Google's large Python codebase.
 - Large Python projects: Mercurial, NumPy, Twisted, etc.
 - Randomized testing.



Status Report

- Two releases so far:
 - 2009Q1: 15-20% faster than CPython.
 - cPickle 2x faster.
 - 2009Q2: 10% faster than Q1; full JIT on top of LLVM.
- 2009Q3: stabilizing, close to release.
 - Optimized LOAD_GLOBAL opcode.
 - Optimized calls to C functions.
 - Less unnecessary error checking.
 - Better constant propagation.
 - More data exposed to LLVM
 - gdb, oprofile support.
 - 20-75% faster than Q2.



Looking Forward: Q4

- 2009Q4:
 - More typefeed back!
 - More inlining!
 - More Clang compilation!
 - Fewer frame allocations!
 - Fewer GIL checks!
 - Begin merger with CPython!



GIL?



Fin

Questions?

http://code.google.com/p/unladen-swallow/

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Fin

Backup Slides



Wednesday, October 7, 2009

Make it faster: specialize dynamically



Wednesday, October 7, 2009

Make it faster: LOAD_GLOBAL

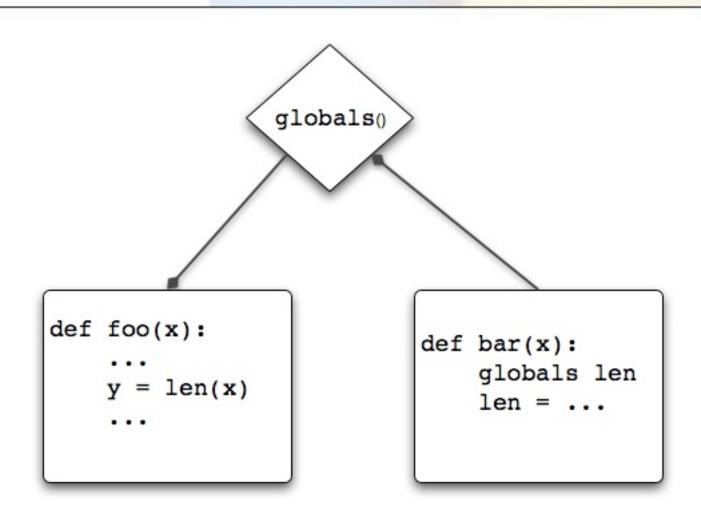
```
LOAD GLOBAL 7 (len)
x = PyDict GetItem(globals, "len")
if (x == NULL) {
   x = PyDict GetItem(builtins, "len")
   if (x == NULL) {
      PyErr NoGlobals()
      return -1;
```

Make it faster: LOAD_GLOBAL

```
LOAD_GLOBAL 7 (len)
if (world has not changed) {
   x = (PyObject *)11712432
else {
   goto bail to interpreter
```



Make it faster: if (world_has_not_changed) {





Make it faster: specialize dynamically

```
def template(data, rows):
   for row in rows:
       data.append("")
       for col in row:
          data.append("%s" % col)
       data.append("")
>>> our data = []
>>> template(our data, our rows)
>>> print "".join(our data)
```



Make it faster: call sites

```
data.append("%s" % col)
```



```
LOAD_FAST 0 (data)

LOAD_ATTR 0 (append)

LOAD_CONST 1 ('%s')

LOAD_FAST 1 (col)

BINARY_MODULO

CALL FUNCTION 1
```



Make it faster: call sites

```
LOAD FAST
                         0 (data)
    LOAD ATTR
                         0 (append)
    CALL FUNCTION
data = locals[0];
if (Py TYPE(data) != EXPECTED TYPE)
   goto bail to interpreter;
if (Py TYPE VERSION(data) != EXPECTED VERSION)
   goto bail to interpreter;
// LOAD CONST
// LOAD FAST
// BINARY MODULO
retval = list append(data, modulo result);
```

Wednesday, October 7, 2009