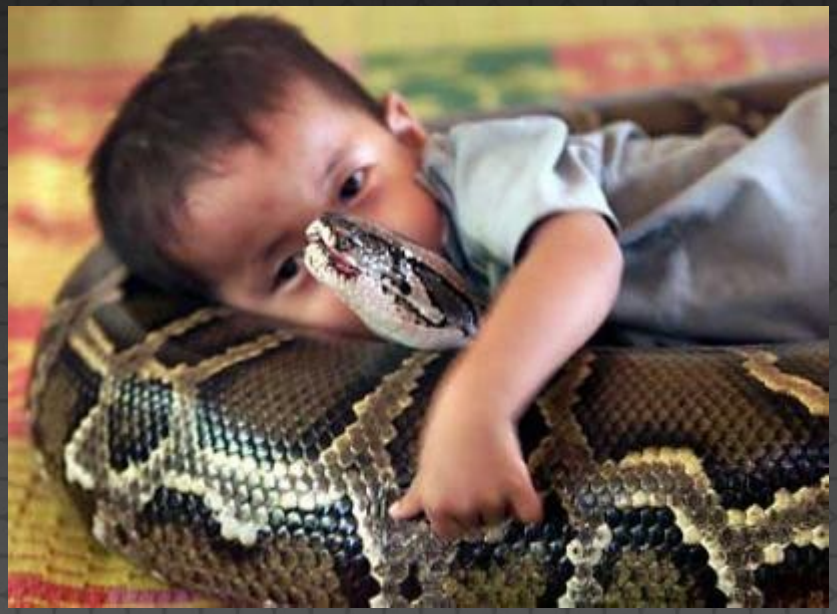
FAT Python

New static optimizer for CPython 3.6



FOSDEM 2016, Bruxelles

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Agenda

(1) Python is slow

(2) Guards, specialization & AST

(3) Optimizations

(4) Implementation

(5) Coming next

Agenda

(1) Python is slow

(1) Python is slow

- CPython is **slower than C**, "compiled" language
- **Slower than JavaScript** and its fast JIT compilers

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(1) Faster Python

- PyPy JIT
- Pyston JIT (LLVM)
- Pyjion JIT (CoreCLR)
- Numba JIT (LLVM), specific to numpy
- Cython static optimizer

(1) New optimizer?

- None replaced CPython yet
- PyPy is not always faster than CPython
- CPython remains the reference implementation for new features
- Many libraries rely on CPython "implementation details" like the Python C API

(1) Simplified goal

```
def func():
    return len("abc")
```

```
def func():
    return 3
```

(1) Problem

Everything is mutable in Python:

- Builtin functions
- Function code
- Global variables
- etc.

(1) Problem

Replace builtin `len()` function:

```
builtins.len = lambda obj: "mock!"
print(len("abc"))
```

Output:

```
mock!
```

(1) My previous attempts

- astoptimizer: simple AST optimizer
- registervm: register-based bytecode
- Bad feedback, both broke deeply the Python semantics, too many assumptions without using guards

(1) Constraints

- Respect the Python semantics
- Don't break applications
- Don't require to modify the application source code

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(2) Guards, specialization & AST

(2) Guards

- Efficient optimizations relying on assumptions
- Guards **check** these assumptions **at runtime**
- Example: was the builtin `len()` function modified?

(2) Namespace

Core feature of the Python language:

- Module: global variables
- Function: local variables
- Class: type.method()
- Instance: obj.attr
- etc.

(2) Namespace guards

- Namespaces are Python `dict`
- Technical challenge: make guard faster than dict lookups
- Solution: PEP 509, add a version to `dict`

(2) Specialize code

- Optimize the code with assumptions: “specialized” code
- Use guards to only call the specialized code if assumptions are still correct
- Example: specialize code if `x` and `y` parameters are `int`

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(2) Specialize code

Pseudo code:

```
def call(func, args):
    if check_guards(args):
        # nothing changed
        code = func.__specialized__
    else:
        # len() was replaced
        code = func.__code__
    execute(code, args)
```

(2) Peephole optimizer

Optimize bytecode:

- Constant folding
- Dead code elimination
- Optimize jumps
- Written in C, very limited

(2) AST

Abstract Syntax Tree:

.py file → tokens → **AST** → bytecode

AST of `len("abc")`:

```
Call(func=Name(id='len', ctx=Load()),
     args=[Str(s='abc')])
```

(2) AST optimizer

```
import ast

class Optimizer(ast.NodeTransformer):
    def visit_Call(self, node):
        return ast.Num(n=3)
```

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(3) Optimizations

(3) Call builtin functions

```
len('abc') → 3

int('123') → 123

pow(2, 8) → 256
```

```
frozenset('abc') → frozenset('abc')
```

built at runtime — constant

Need a guard on the called function

(3) Simplify iterables

```
for x in range(3)  ⟶ for x in (0, 1, 2)
for x in [7, 9]    ⟶ for x in (7, 9)
for x in {}        ⟶ for x in ()
```

Replacing `range(...)` requires a guard on the `range()` function

(3) Loop unrolling

```
for x in (1, 2, 3):
    print(x)
```

```
x = 1
print(x)

x = 2
print(x)

x = 3
print(x)
```

(3) Copy constants

```
x = 1
print(x)
```

```
x = 1
print(1)
```

```
x = 2
print(x)
```

```
x = 2
print(2)
```

```
x = 3
print(x)
```

```
x = 3
print(3)
```

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(3) Constant folding

```
+(5) → 5

x in [1, 2, 3] → x in (1, 2, 3)

(7,) * 3 → (7, 7, 7)

'python2.7'[:-2] → 'python'

'P' in 'Python' → True

[5, 9, 20][1] → 9
```

(3) Copy to constants

Python code:

```
def func(obj):
    return len(obj)
```

Bytecode:

```
LOAD_GLOBAL 'len'
...
```

→

Bytecode:

```
LOAD_CONST 'len'
...
```

Need a guard on `len()` builtin

(3) Remove dead code

```
if test:                    →  if not test:
    pass                           else_block
else:
    else_block

if 0:                       →  pass
    body_block

return result               →  return result
dead_code
```

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(4) Implementation

(4) Merged changes

New AST node `ast.Constant` to simplify optimizers. Converted to `ast.Constant` by the optimizer:

- `ast.NameConstant`: `None`, `True`, `False`
- `ast.Num`: `int`, `float`, `complex`
- `ast.Str`: `str`
- `ast.Bytes`: `bytes`
- `ast.Tuple` (if items are constant): tuple

(4) Merged changes

Support negative line number delta:

```
for x in (50, 100): # line 1
    print(x)        # line 2 (+1)
```

```
x = 50      # line 1
print(x)    # line 2 (+1)
x = 100     # line 1 (-1)
print(x)    # line 2 (+1)
```

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(4) Merged changes

Support `tuple` and `frozenset` constants in the compiler:

```
obj in {1, 2, 3}
```

```
obj in frozenset({1, 2, 3})
```

(4) PEP 509: dict version

- Add a version to Python `dict`
- Version is incremented at every change
- Version is unique for all dicts
- Guard compares the version: avoid dict lookup if nothing changed

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(4) PEP 509: dict version

```
def check(self):
    version = dict_get_version(self.dict)
    if version == self.version:
        return True  # Fast-path: no lookup

    value = self.dict.get(self.key, UNSET)
    if value is self.value:
        self.version = version
        return True

    return False   # the key was modified
```

(4) PEP 510: Specialize

- Add `PyFunction_Specialize()` C function
- Specialized code can be a code object (bytecode) or any callable object
- Modify `Python/ceval.c` to check guards and use specialized code

(4) PEP 510: Specialize

Specialize code using:

- New AST optimizers: fatoptimizer
- Cython
- Pythran
- Numba
- etc.

(4) PEP 510: Specialize

```
def func():
    return chr(65)

def fast_func():
    return 'A'

fat.specialize(
            func,
            fast_func.__code__,
            [fat.GuardBuiltins('chr')])
```

(4) PEP 511: Transformer

- Add `-o` command line option
- Add `sys.set_code_transformers()`
- A code transformer can modify the bytecode and/or the AST

(4) Python 3.6?

- Good feedback on the 3 PEPs
- **Requirement: speedup on applications**
- Today only faster on microbenchmarks
- Need 6 months to implement more optimizations

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(5) Coming next

(5) Remove unused vars

```
x = 1
print(1)
```

```
print(1)
```

```
x = 2
print(2)
```

```
print(2)
```

```
x = 3
print(3)
```

```
print(3)
```

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(5) Copy globals

```
KEYS = {2: 55}

def func():
    return KEYS[2]
```

```
KEYS = {2: 55}

def func():
    return 55
```

Need a guard on the KEYS global

(5) Function inlining

```
def incr(x):
    return x+1

y = inc(3)
```

```
def incr(x):
    return x+1

y = 3 + 1
```

Need a guard on the `incr()` function

(5) Profiling

- Run the application in a profiler
- Record types of function parameters
- Generate type annotations
- Use these types to specialize the code

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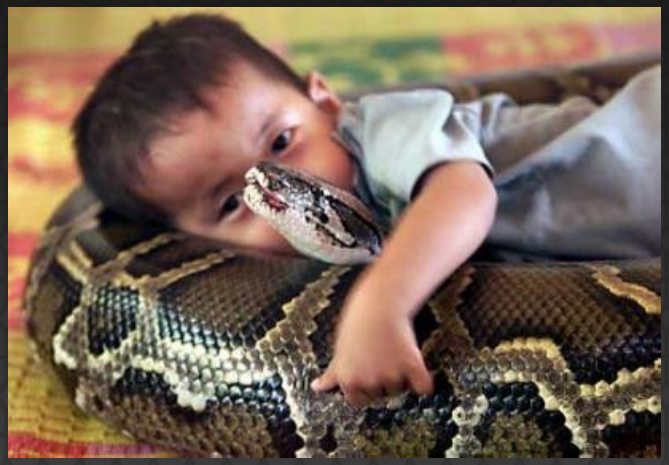
What is this?



Three-year-old Cambodian boy Oeun Sambat hugs his best friend, a four-metre (13.1 feet) long female python named Chamreun or 'Lucky' in the village of Sit Tbow on May 18, 2003

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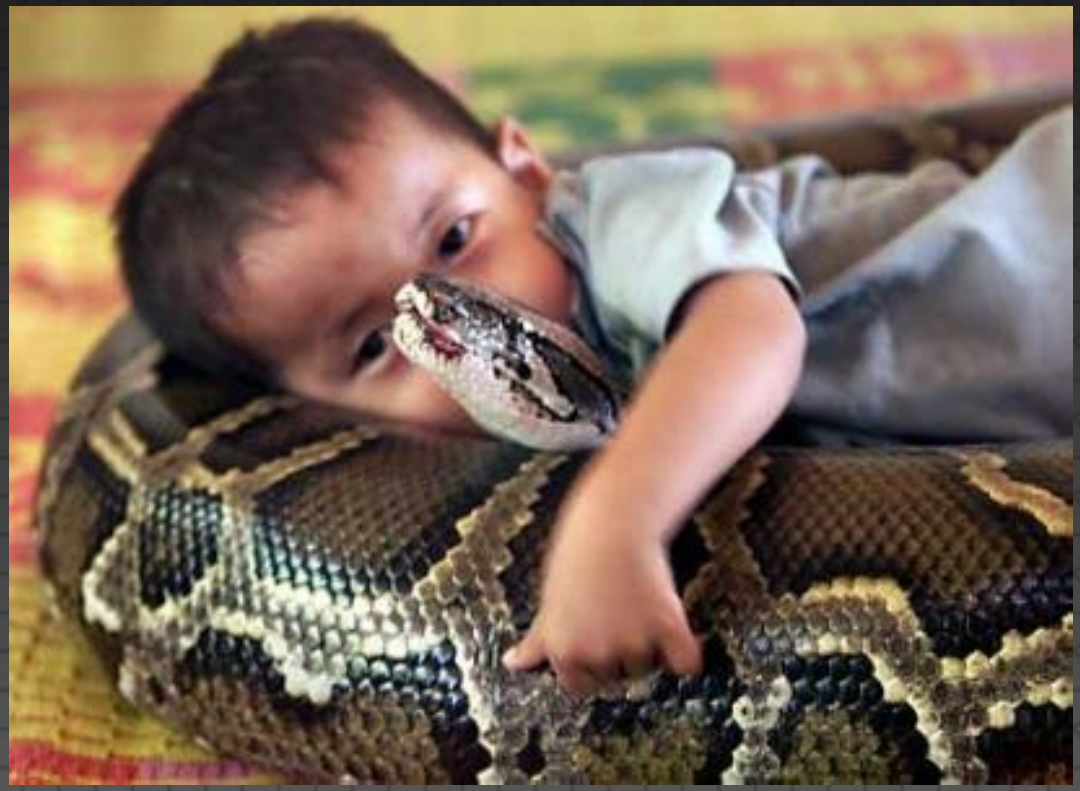
Video

https://www.facebook.com/ithinktwice/videos/1526860615771160/

Questions?



http://faster-cpython.rtfd.org/fat_python.html

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