Python性能优化技巧及原理

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课程介绍

1. Python性能分析
2. Python性能优化的技巧
3. Python性能优化实践

背景知识

- 适当的Python开发基础
- 常用Python性能分析工具和方法
- 少量的C语言代码阅读调试知识

1. 少造轮子

Python的标准库核心组件大都是用经过优化的C语言写成的。因此不需要你自建，而且你自建的很可能会更慢。使用Python给定的数据结构，列表、元组、集合和字典这些数据类型，不要去在Python层去自定义。使用Python核心库组件的算法，少造轮子。

1.1 二分查找

二分查找是大家比较容易接触到的一个算法，应用也很广泛。

- ### 一个轮子：

```
def bsearch(a, x, lo=0, hi=None):
    if lo < 0:
        raise ValueError('lo must be non-negative')
    if hi is None:
        hi = len(a)
    while lo < hi:
        mid = (lo+hi)//2
        if a[mid] < x: lo = mid+1
        else: hi = mid
    return lo
```

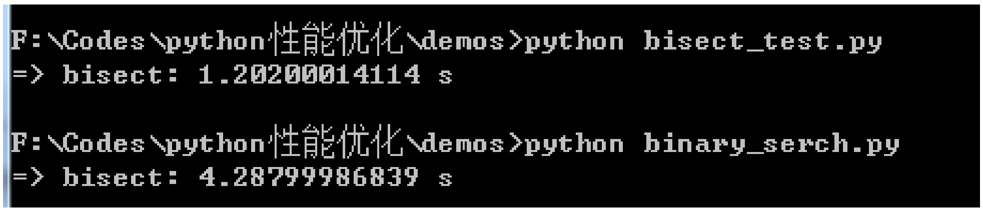
- 使用库函数：

```
import bisect
bisect.bisect_left(a,k)
```

- 性能测试：

```
with timer.Timer() as t:
    a = range(1000*1000)
    for i in xrange(1000*1000):
        k = 100
        bisect.bisect_left(a,k)# or bsearch(a, k)
print "=> bisect: %s s" % t.secs
```

- 测试结果：



```
F:\Codes\python性能优化\demos>python bisect_test.py
=> bisect: 1.20200014114 s

F:\Codes\python性能优化\demos>python binary_serch.py
=> bisect: 4.28799986839 s
```

- 原因分析：
    - 源码分析 **Python-src\Modules_bisectmodule.c**
    - **python**调试演示
    - **windows c**语言**python**源码调试演示

1.2 排序

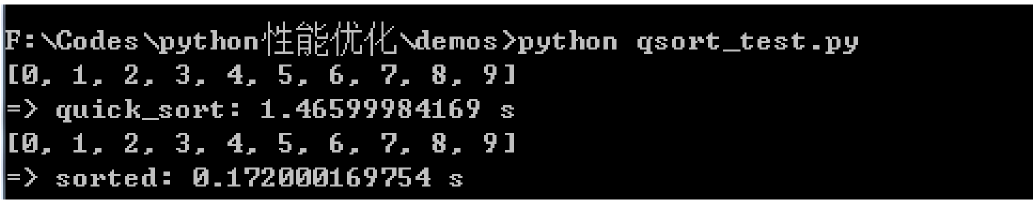
- 一个轮子：

```
def quick_sort(lists, left, right):
    # 快速排序
    if left >= right:
        return lists
    key = lists[left]
    low = left
    high = right
    while left < right:
        while left < right and lists[right] >= key:
            right -= 1
        lists[left] = lists[right]
        while left < right and lists[left] <= key:
            left += 1
        lists[right] = lists[left]
    lists[right] = key
    quick_sort(lists, low, left - 1)
    quick_sort(lists, left + 1, high)
    return lists
```

- 对应的库函数:

```
l = [6,4,2,1,7,8,9,3,0,5]
rs = sorted(l)
```

- 执行**1000**次性能测试:



```
F:\Codes\python性能优化\demos>python qsort_test.py
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
=> quick_sort: 1.46599984169 s
[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
=> sorted: 0.172000169754 s
```

- 原因分析：

  ###python源码定位###

```
Python-src\Python\bltinmodule.c      builtin_sorted
Python-src\Objects\listobject.c      PyList_Sort
```

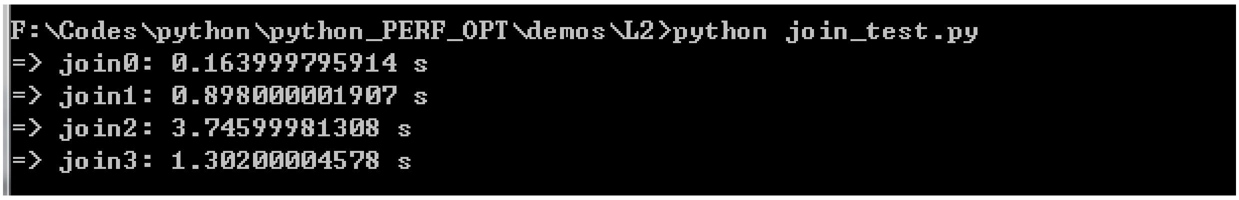
2. 使用效率更高的语法

2.1 字符串连接

- 先做一个小测试:

```python
#join_test.py
import timer
jlist_long = ["a",  "b", "a",  "b","a",  "b","a",  "b","a",  "b" ]
jlist_short =  ["a",  "b"]
MAX_RANGE =  10 * 1000 * 1000
def test_join0():
    for i in xrange(MAX_RANGE):
        rs =  "a" + "b"

def test_join1():
    for i in xrange(MAX_RANGE):
        rs =  "".join(jlist_short)

def test_join2():
    for i in xrange(MAX_RANGE):
            rs = jlist_long[0] +  jlist_long[1] +  jlist_long[2] +  jlist_long[3] +
jlist_long[4] +  jlist_long[5] +  jlist_long[6] +  jlist_long[7] + jlist_long[8] +
jlist_long[9]

def test_join3():
    for i in xrange(MAX_RANGE):
            rs =  "".join(jlist_long)
```

- ## 性能测试展示

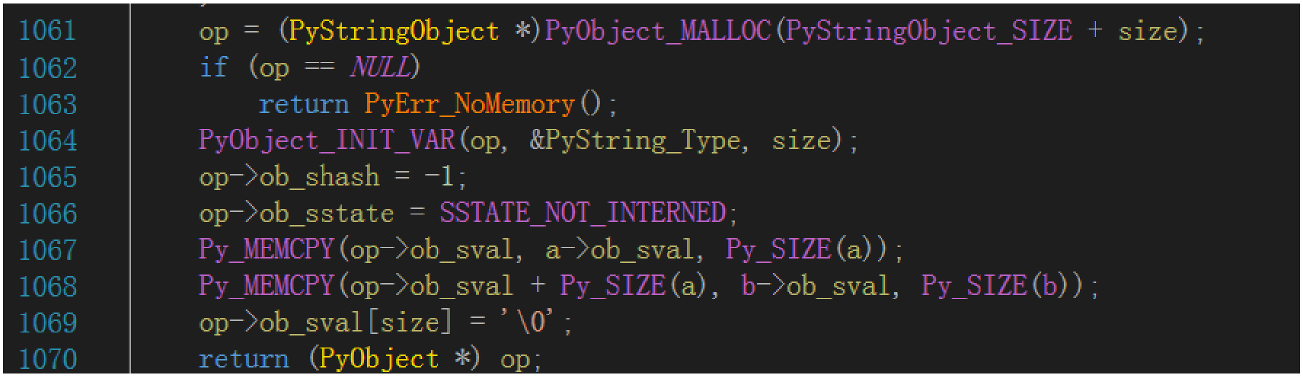


```
F:\Codes\python\python_PERF_OPT\demos\L2>python join_test.py
=> join0: 0.163999795914 s
=> join1: 0.898000001907 s
=> join2: 3.74599981308 s
=> join3: 1.30200004578 s
```

- 结论
    - 简短的字符串连接，可以用+
    - 连接一个list用join

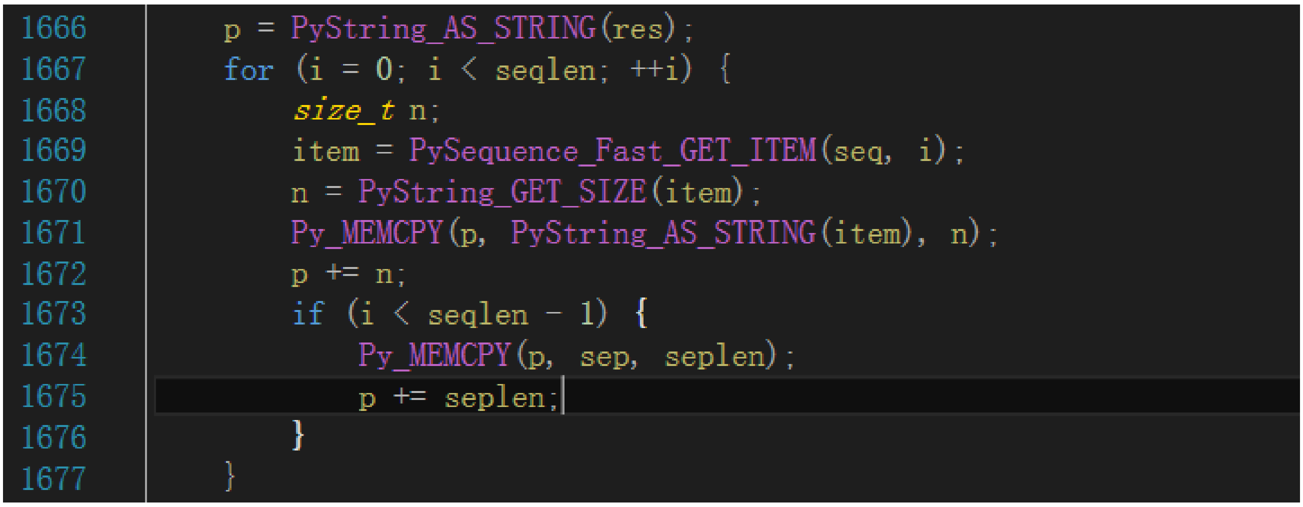
- ## 源代码分析:

"+" 连接字符串 Python-2.7.9-src\Objects\stringobject.c -> string_concat



```c
    op = (PyStringObject *)PyObject_MALLOC(PyStringObject_SIZE + size);
    if (op == NULL)
        return PyErr_NoMemory();
    PyObject_INIT_VAR(op, &PyString_Type, size);
    op->ob_shash = -1;
    op->ob_sstate = SSTATE_NOT_INTERNED;
    Py_MEMCPY(op->ob_sval, a->ob_sval, Py_SIZE(a));
    Py_MEMCPY(op->ob_sval + Py_SIZE(a), b->ob_sval, Py_SIZE(b));
    op->ob_sval[size] = '\0';
    return (PyObject *) op;
```

join连接字符串 Python-2.7.9-src\Objects\stringobject.c -> string_join



```
    p = PyString_AS_STRING(res);
    for (i = 0; i < seqlen; ++i) {
        size_t n;
        item = PySequence_Fast_GET_ITEM(seq, i);
        n = PyString_GET_SIZE(item);
        Py_MEMCPY(p, PyString_AS_STRING(item), n);
        p += n;
        if (i < seqlen - 1) {
            Py_MEMCPY(p, sep, seplen);
            p += seplen;
        }
    }
```

2.2 range和xrange（python3不适用）

- 效率不好的语法

```
for i in range(1000):
    dosomething()
```

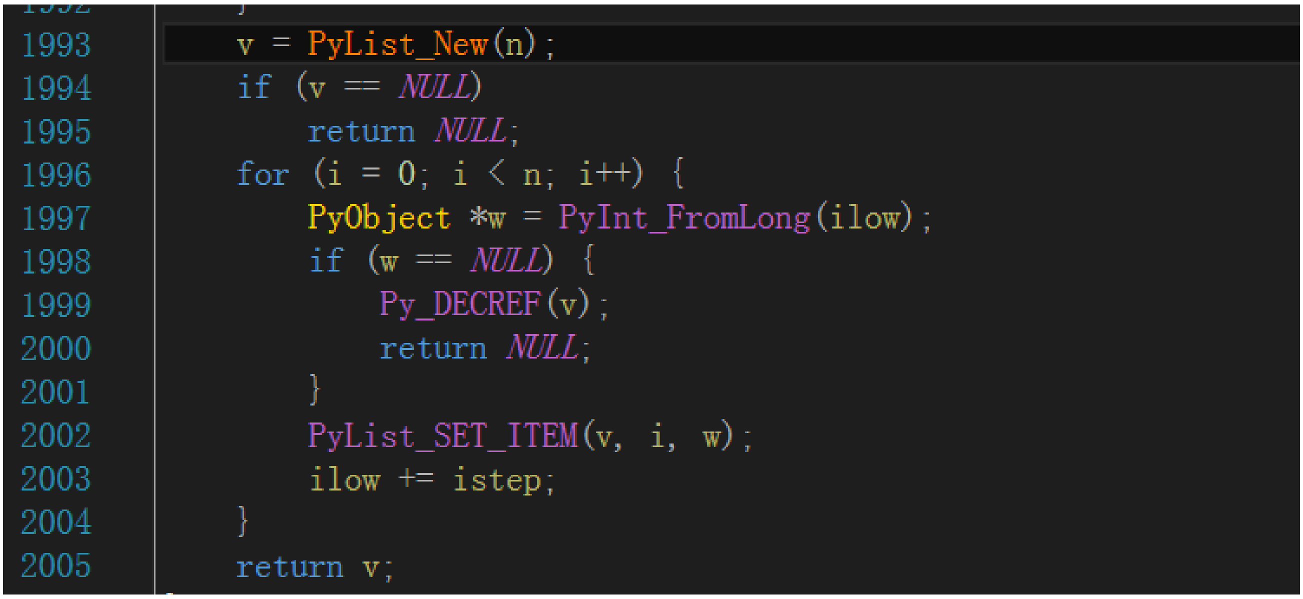
- 效率改进

```
for i in xrange(1000):
    dosomething()
```

- 原因分析：

从下图是range的关键代码，由此看出range的本质就是创建一个list。

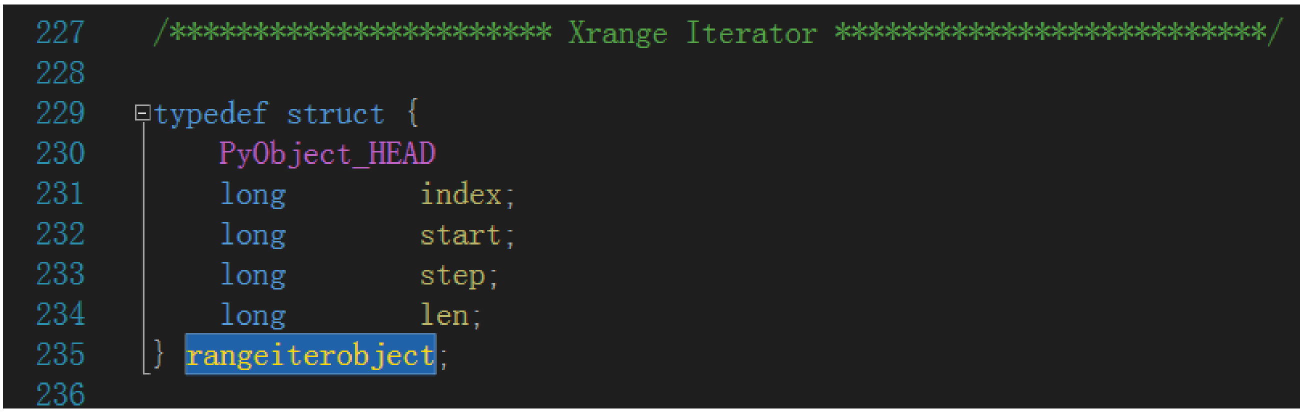
Python-2.7.9-src\Python\bltinmodule.c -> builtin_range



```
    v = PyList_New(n);
    if (v == NULL)
        return NULL;
    for (i = 0; i < n; i++) {
        PyObject *w = PyInt_FromLong(ilow);
        if (w == NULL) {
            Py_DECREF(v);
            return NULL;
        }
        PyList_SET_ITEM(v, i, w);
        ilow += istep;
    }
    return v;
```

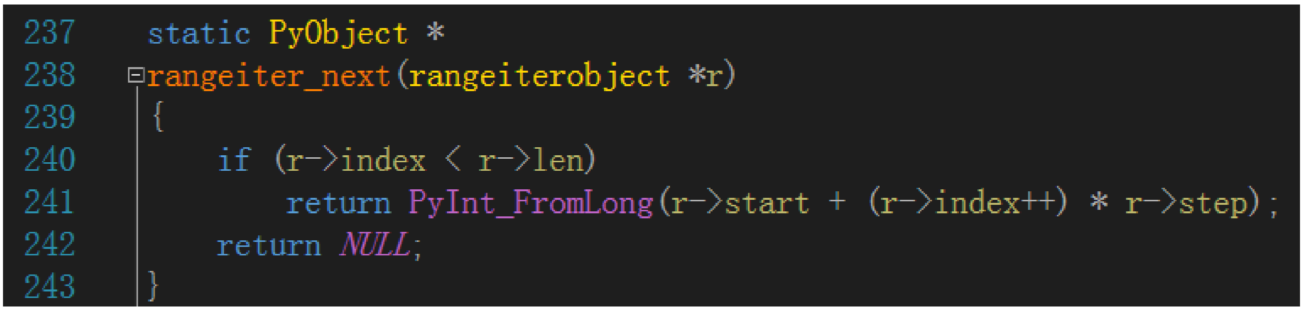
下面来看xrange，在python中调用xrange会创建下边这个结构体

Python-2.7.9-src\Objects\rangeobject.c (下列三幅图，都来自此文件)



```
/*********************** Xrange Iterator **************************/

typedef struct {
    PyObject_HEAD
    long        index;
    long        start;
    long        step;
    long        len;
} rangeiterobject;

```

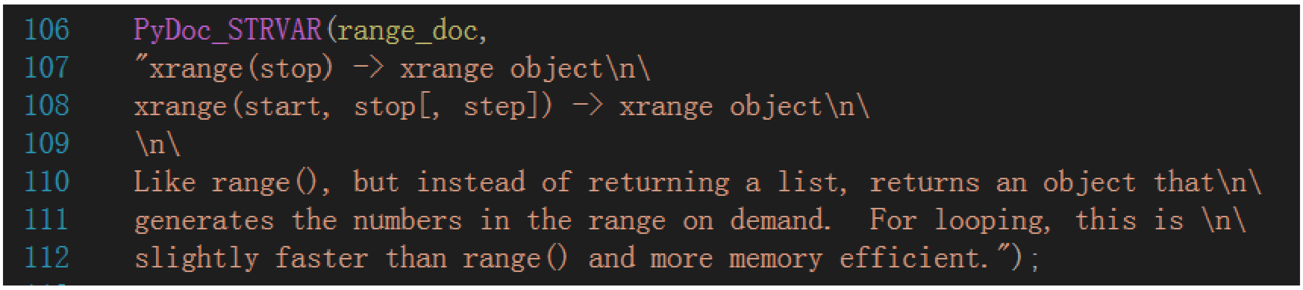
然后直接开始迭代



```
static PyObject *
rangeiter_next(rangeiterobject *r)
{
    if (r->index < r->len)
        return PyInt_FromLong(r->start + (r->index++) * r->step);
    return NULL;
}
```

较大量的数字序列的话，range在生成list这一步需要开辟内存空间并赋值，相比下xrange的效率就好很多了。

其实python源码中已经写的很清楚了，xrange这种生成器的方式确实比range效率要高。



```
PyDoc_STRVAR(range_doc,
"xrange(stop) -> xrange object\n\
xrange(start, stop[, step]) -> xrange object\n\
\n\
Like range(), but instead of returning a list, returns an object that\n\
generates the numbers in the range on demand.  For looping, this is \n\
slightly faster than range() and more memory efficient.");
```

2.3 循环优化

- 将列表中的所有单词变成大写的一般写法

```
newlist = []
for word in oldlist:
    newlist.append(word.upper())
```

2.3.1列表推导

```
newlist = [s.upper() for s in oldlist]
```

- 带if语句的列表推导

```
names = ['Bob','Tom','alice','Jerry','Wendy','Smith']
newlist = []
for name in names:
    if len(name) > 3:
        newlist.append(name.upper())
```

```
names = ['Bob','Tom','alice','Jerry','Wendy','Smith']
newlist = [name.upper() for name in names if len(name)>3]
```

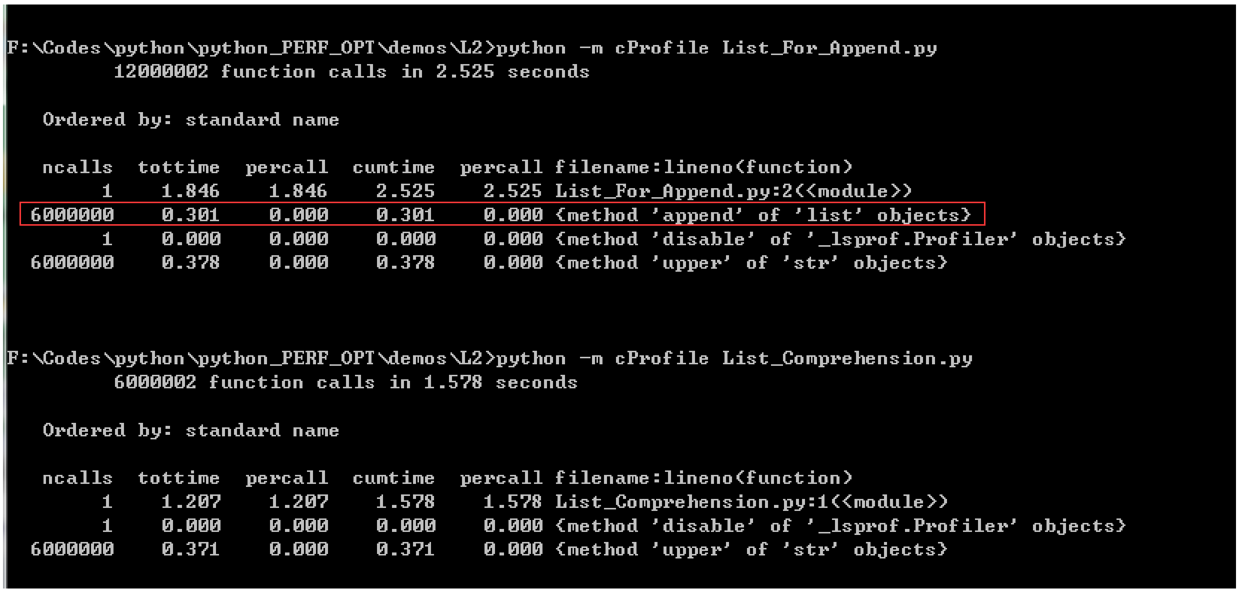
- 字典推导

```
strings = ['import','is','with','if','file','exception']
D = {key: val for val,key in enumerate(strings)}
>>> D
{'exception': 5, 'is': 1, 'file': 4, 'import': 0, 'with': 2, 'if': 3}
```

- 集合推导

```
strings = ['a','is','with','if','file','exception']
S = {len(s) for s in strings}
>>>S
set([1, 2, 4, 9])#set 没有重复项
```

- ## 性能比较



```
F:\Codes\python\python_PERF_OPT\demos\L2>python -m cProfile List_For_Append.py
         12000002 function calls in 2.525 seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        1    1.846    1.846    2.525    2.525 List_For_Append.py:2(<module>)
  6000000    0.301    0.000    0.301    0.000 {method 'append' of 'list' objects}
        1    0.000    0.000    0.000    0.000 {method 'disable' of '_lsprof.Profiler' objects}
  6000000    0.378    0.000    0.378    0.000 {method 'upper' of 'str' objects}



F:\Codes\python\python_PERF_OPT\demos\L2>python -m cProfile List_Comprehension.py
         6000002 function calls in 1.578 seconds

   Ordered by: standard name

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        1    1.207    1.207    1.578    1.578 List_Comprehension.py:1(<module>)
        1    0.000    0.000    0.000    0.000 {method 'disable' of '_lsprof.Profiler' objects}
  6000000    0.371    0.000    0.371    0.000 {method 'upper' of 'str' objects}
```

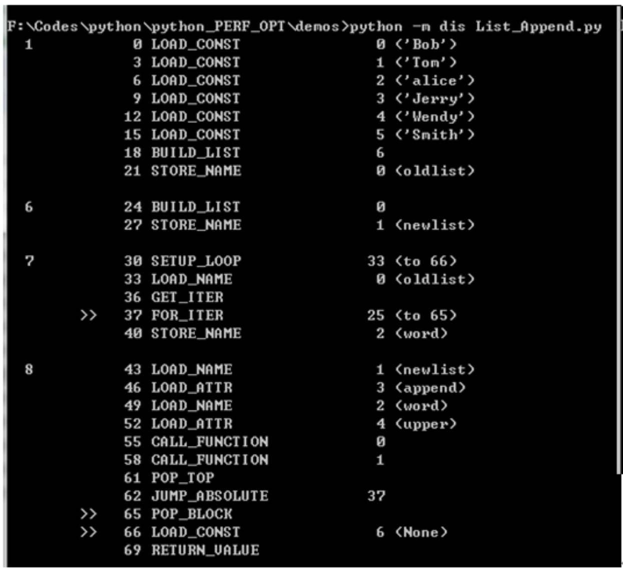
- ## 原因分析

之前的几次性能分析都是使用源码和调试的方式，这次换一种分析方式，字节码比较。

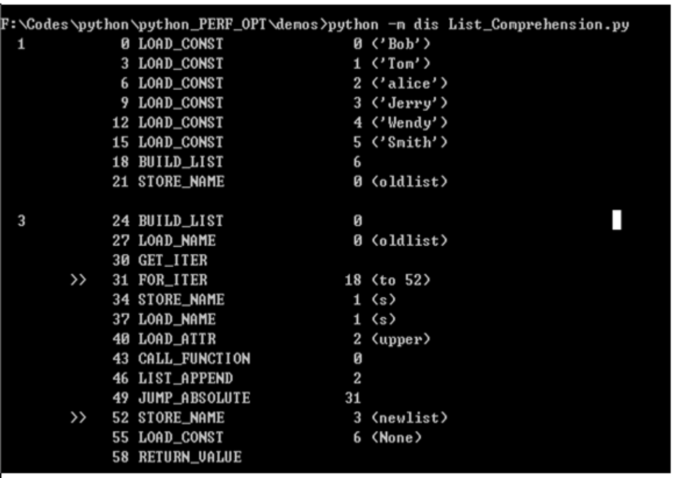
Python虽然是一个解释型语言，但是代码最终还是会编译成字节码，字节码需要处理才能被理解，dis模块把字节码转换成人能读懂的形式，然后我们进行分析。

```
python -m dis xxx.py
```

字节码比较：

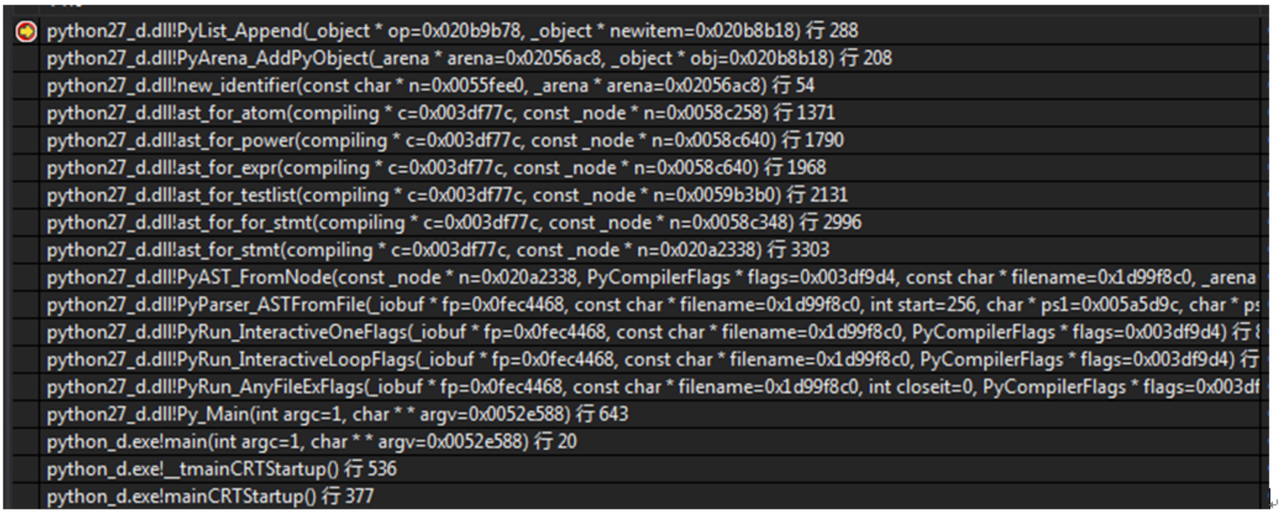


```
F:\Codes\python\python_PERF_OPT\demos>python -m dis List_Append.py
  1           0 LOAD_CONST               0 ('Bob')
              3 LOAD_CONST               1 ('Tom')
              6 LOAD_CONST               2 ('alice')
              9 LOAD_CONST               3 ('Jerry')
             12 LOAD_CONST               4 ('Wendy')
             15 LOAD_CONST               5 ('Smith')
             18 BUILD_LIST               6
             21 STORE_NAME               0 (oldlist)

  6          24 BUILD_LIST               0
             27 STORE_NAME               1 (newlist)

  7          30 SETUP_LOOP              33 (to 66)
             33 LOAD_NAME                0 (oldlist)
             36 GET_ITER
        >>   37 FOR_ITER                25 (to 65)
             40 STORE_NAME               2 (word)

  8          43 LOAD_NAME                1 (newlist)
             46 LOAD_ATTR                3 (append)
             49 LOAD_NAME                2 (word)
             52 LOAD_ATTR                4 (upper)
             55 CALL_FUNCTION            0
             58 CALL_FUNCTION            1
             61 POP_TOP
             62 JUMP_ABSOLUTE           37
        >>   65 POP_BLOCK
        >>   66 LOAD_CONST               6 (None)
             69 RETURN_VALUE
```

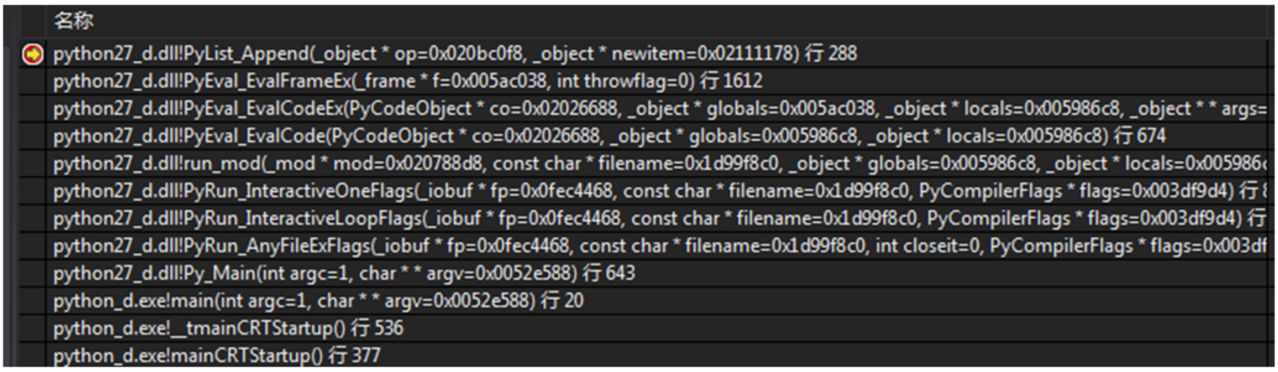


```
F:\Codes\python\python_PERF_OPT\demos>python -m dis List_Comprehension.py
  1           0 LOAD_CONST               0 ('Bob')
              3 LOAD_CONST               1 ('Tom')
              6 LOAD_CONST               2 ('alice')
              9 LOAD_CONST               3 ('Jerry')
             12 LOAD_CONST               4 ('Wendy')
             15 LOAD_CONST               5 ('Smith')
             18 BUILD_LIST               6
             21 STORE_NAME               0 (oldlist)

  3          24 BUILD_LIST               0
             27 LOAD_NAME                0 (oldlist)
             30 GET_ITER
        >>   31 FOR_ITER                18 (to 52)
             34 STORE_NAME               1 (s)
             37 LOAD_NAME                1 (s)
             40 LOAD_ATTR                2 (upper)
             43 CALL_FUNCTION            0
             46 LIST_APPEND              2
             49 JUMP_ABSOLUTE           31
        >>   52 STORE_NAME               3 (newlist)
             55 LOAD_CONST               6 (None)
             58 RETURN_VALUE
```

List_Append调用栈比较：



```
python27_d.dll!PyList_Append(_object * op=0x020b9b78, _object * newitem=0x020b8b18) 行 288
python27_d.dll!PyArena_AddPyObject(_arena * arena=0x02056ac8, _object * obj=0x020b8b18) 行 208
python27_d.dll!new_identifier(const char * n=0x0055fee0, _arena * arena=0x02056ac8) 行 54
python27_d.dll!ast_for_atom(compiling * c=0x003df77c, const _node * n=0x0058c258) 行 1371
python27_d.dll!ast_for_power(compiling * c=0x003df77c, const _node * n=0x0058c640) 行 1790
python27_d.dll!ast_for_expr(compiling * c=0x003df77c, const _node * n=0x0058c640) 行 1968
python27_d.dll!ast_for_testlist(compiling * c=0x003df77c, const _node * n=0x0059b3b0) 行 2131
python27_d.dll!ast_for_for_stmt(compiling * c=0x003df77c, const _node * n=0x0058c348) 行 2996
python27_d.dll!ast_for_stmt(compiling * c=0x003df77c, const _node * n=0x020a2338) 行 3303
python27_d.dll!PyAST_FromNode(const _node * n=0x020a2338, PyCompilerFlags * flags=0x003df9d4, const char * filename=0x1d99f8c0, _arena
python27_d.dll!PyParser_ASTFromFile(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, int start=256, char * ps1=0x005a5d9c, char * ps
python27_d.dll!PyRun_InteractiveOneFlags(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, PyCompilerFlags * flags=0x003df9d4) 行
python27_d.dll!PyRun_InteractiveLoopFlags(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, PyCompilerFlags * flags=0x003df9d4) 行
python27_d.dll!PyRun_AnyFileExFlags(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, int closeit=0, PyCompilerFlags * flags=0x003df
python27_d.dll!Py_Main(int argc=1, char * * argv=0x0052e588) 行 643
python_d.exe!main(int argc=1, char * * argv=0x0052e588) 行 20
python_d.exe!__tmainCRTStartup() 行 536
python_d.exe!mainCRTStartup() 行 377
```



```
名称
python27_d.dll!PyList_Append(_object * op=0x020bc0f8, _object * newitem=0x02111178) 行 288
python27_d.dll!PyEval_EvalFrameEx(_frame * f=0x005ac038, int throwflag=0) 行 1612
python27_d.dll!PyEval_EvalCodeEx(PyCodeObject * co=0x02026688, _object * globals=0x005ac038, _object * locals=0x005986c8, _object * * args=
python27_d.dll!PyEval_EvalCode(PyCodeObject * co=0x02026688, _object * globals=0x005986c8, _object * locals=0x005986c8) 行 674
python27_d.dll!run_mod(_mod * mod=0x020788d8, const char * filename=0x1d99f8c0, _object * globals=0x005986c8, _object * locals=0x005986
python27_d.dll!PyRun_InteractiveOneFlags(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, PyCompilerFlags * flags=0x003df9d4) 行
python27_d.dll!PyRun_InteractiveLoopFlags(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, PyCompilerFlags * flags=0x003df9d4) 行
python27_d.dll!PyRun_AnyFileExFlags(_iobuf * fp=0x0fec4468, const char * filename=0x1d99f8c0, int closeit=0, PyCompilerFlags * flags=0x003df
python27_d.dll!Py_Main(int argc=1, char * * argv=0x0052e588) 行 643
python_d.exe!main(int argc=1, char * * argv=0x0052e588) 行 20
python_d.exe!__tmainCRTStartup() 行 536
python_d.exe!mainCRTStartup() 行 377
```

2.3.2 map函数

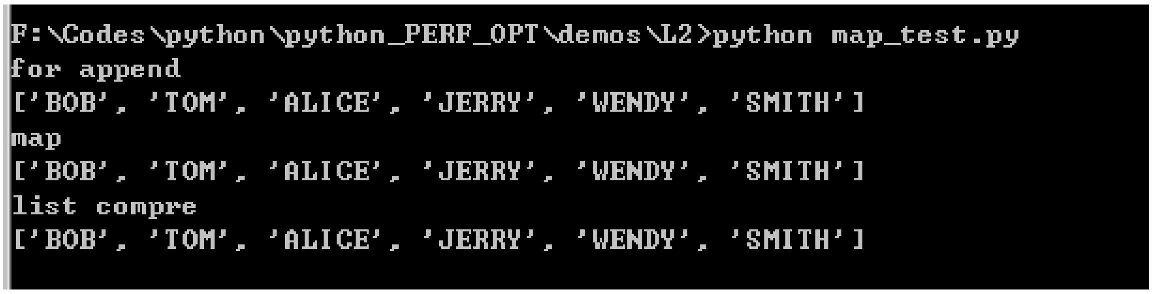
- 进行优化

  map()接收一个函数 f 和一个 list，并通过把函数 f 依次作用在 list 的每个元素上，得到一个新的 list 并返回

```
map(doSomethingWithX, xrange(0,100))
```

- 功能对比

```
#map_test.py
oldlist =  ['Bob','Tom','alice','Jerry','Wendy','Smith']
newlist = []
for word in oldlist:
    newlist.append(word.upper())
print newlist

oldlist =  ['Bob','Tom','alice','Jerry','Wendy','Smith']
newlist = map(lambda x: x.upper(),oldlist)
print newlist

oldlist =  ['Bob','Tom','alice','Jerry','Wendy','Smith']
newlist = [s.upper() for s in oldlist]
print newlist
```



```
F:\Codes\python\python_PERF_OPT\demos\L2>python map_test.py
for append
['BOB', 'TOM', 'ALICE', 'JERRY', 'WENDY', 'SMITH']
map
['BOB', 'TOM', 'ALICE', 'JERRY', 'WENDY', 'SMITH']
list compre
['BOB', 'TOM', 'ALICE', 'JERRY', 'WENDY', 'SMITH']
```

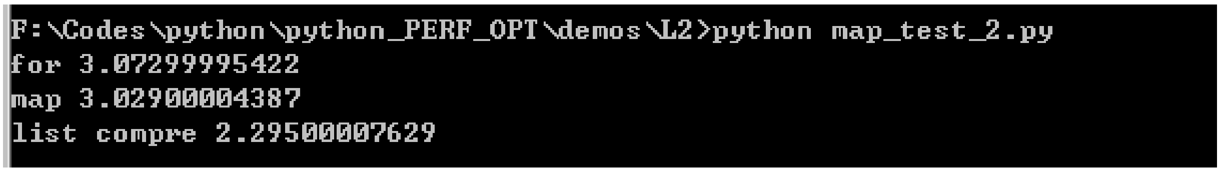
- 原因分析

  原理和列表推导类似

2.3.3 两种方式的优劣

- 继续转成大写字母的例子

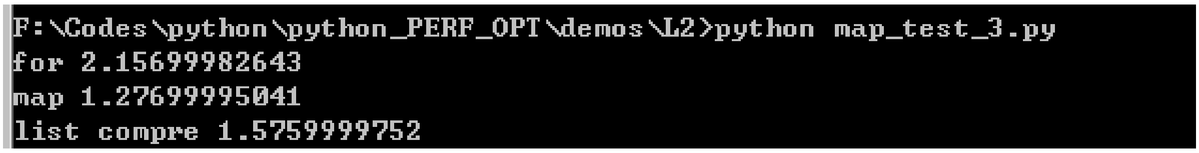
```
#map_test2.py
from timer import *

MAX = 5000000

with Timer() as t:
    for i in xrange(MAX):

        oldlist =  ['Bob','Tom','alice','Jerry','Wendy','Smith']
        newlist = []
        for word in oldlist:
            newlist.append(word.upper())

print "for %s"%t.secs

with Timer() as t:
    for i in xrange(MAX):

        oldlist =  ['Bob','Tom','alice','Jerry','Wendy','Smith']
        newlist = map(lambda x: x.upper(),oldlist)

print "map %s"%t.secs

with Timer() as t:
    for i in xrange(MAX):

        oldlist =  ['Bob','Tom','alice','Jerry','Wendy','Smith']
        newlist = [s.upper() for s in oldlist]

print "list compre %s"%t.secs
```



```
F:\Codes\python\python_PERF_OPT\demos\L2>python map_test_2.py
for 3.07299995422
map 3.02900004387
list compre 2.29500007629
```

- 都使用函数

```
#map_test3.py
from timer import *

MAX = 1000000

oldlist =  range(1, 10)
def doSomethingWithX(x):
    return x*x

with Timer() as t:
    for x in xrange(0, MAX):
        newlist = []
        for x in  oldlist:
            newlist.append(doSomethingWithX(x))
print "for %s"%t.secs

with Timer() as t:
    for x in xrange(0, MAX):
        newlist =  map(doSomethingWithX,  oldlist)
print "map %s"%t.secs

with Timer() as t:
    for x in xrange(0, MAX):
        newlist = [doSomethingWithX(i) for i in  oldlist]
print "list compre %s"%t.secs
```



```
F:\Codes\python\python_PERF_OPT\demos\L2>python map_test_3.py
for 2.15699982643
map 1.27699995041
list compre 1.5759999752
```

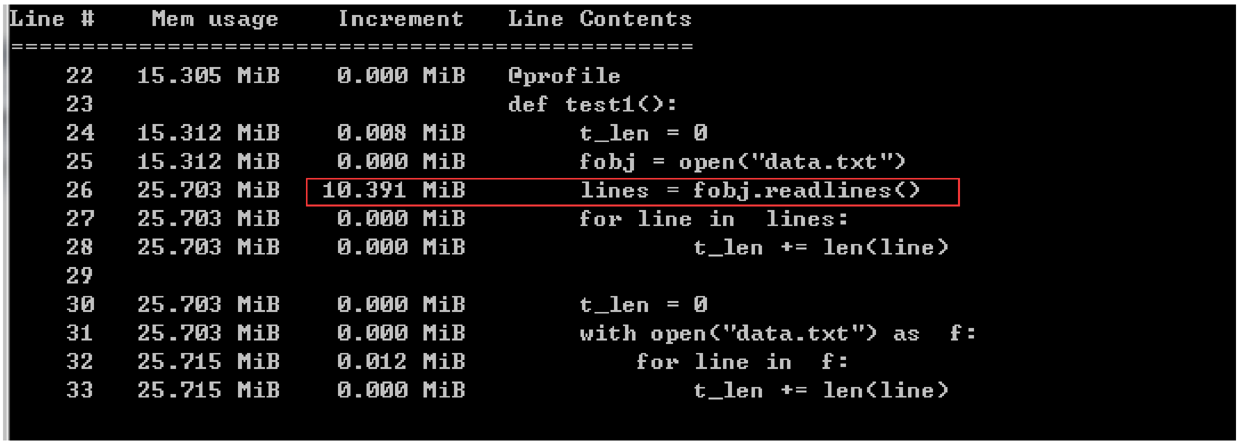
- 结论
    - 如果使用同样的函数，map速度更快
    - 但列表推导的语法更灵活，简单表达式速度更好

2.4 其他技巧

- 文件处理

```
fobj = open("data.txt")
lines = fobj.readlines()#当文件较大时，消耗内存
for line in  lines:
    doSomethingWith(line)
```

```
with open("data.txt") as  f:
    for line in  f:
        doSomethingWith(line)
```



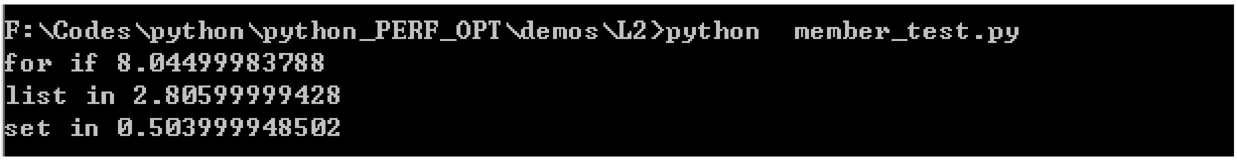
```
Line #    Mem usage    Increment   Line Contents
================================================
    22   15.305 MiB    0.000 MiB   @profile
    23                             def test1():
    24   15.312 MiB    0.008 MiB        t_len = 0
    25   15.312 MiB    0.000 MiB        fobj = open("data.txt")
    26   25.703 MiB   10.391 MiB        lines = fobj.readlines()
    27   25.703 MiB    0.000 MiB        for line in  lines:
    28   25.703 MiB    0.000 MiB                t_len += len(line)
    29
    30   25.703 MiB    0.000 MiB        t_len = 0
    31   25.703 MiB    0.000 MiB        with open("data.txt") as  f:
    32   25.715 MiB    0.012 MiB            for line in  f:
    33   25.715 MiB    0.000 MiB                t_len += len(line)
```

- 在处理大列表的时候，可以使用生成器来动态生成列表元素

```
#my_struct = (x**2 for x in range(100))
my_stucct =  [x**2 for x in range(100)]
for number in my_struct:
    doSomethingWith(number)
```

- 成员关系测试，多用in；查询交集并集等操作，先转换成集合

```
from timer import *

MAX =  10000000
my_list = ['a','b','is','python','jason','hello','hill','with','phone','test',
'dfdf','apple','pddf','ind','basic','none','baecr','var','bana','dd','wrd']
key = "blue"
def test():
    with Timer() as t:
        for i in xrange(MAX):
            rs = False
            for item in my_list:
                if key == item:
                    rs =  True
                    break
    print  "for if %s" % t.secs

    with Timer() as t:
        for i in xrange(MAX):
            rs = False
            if key in my_list:
                rs =  True
    print  "list in %s" % t.secs

    myset = set(my_list)
    with Timer() as t:
            for i in xrange(MAX):
                rs = False
                if key in myset:
                    rs =  True
    print  "set in %s" % t.secs
```



```
F:\Codes\python\python_PERF_OPT\demos\L2>python  member_test.py
for if 8.04499983788
list in 2.80599999428
set in 0.503999948502
```

- 密集循环内，减少函数调用，直接内联代码，可以更加高效，但代价是损害代码的可读性和维护便利性

3. python脚本运行方式

区分两个名词

CPython

Cython

3.1 PyPy

PyPy是Python实现的Python解释器。

- 主要特性-速度

PyPy的一个主要特性是对普通Python代码运行速度的优化。这是由于它使用JIT（Just-in-time）编译器。

- 常见的代码执行方式
    - 编译执行
    - 解释执行

- JIT

JIT技术是两者的结合，首先让代码解释执行，同时收集信息，在收集到足够信息的时候，将代码动态编译成CPU指令，然后用CPU指令替代解释执行的过程，因为编译发生在马上要执行之前，所以叫做Just-In-Time Compiler。编译之后速度就是编译执行的速度了，比解释执行要快得多，所以运用JIT的PyPy很多情况下会比普通的CPython要快。

- 其他特性
    - 内存占用
    - 沙盒
    - 无栈特性
- 安装

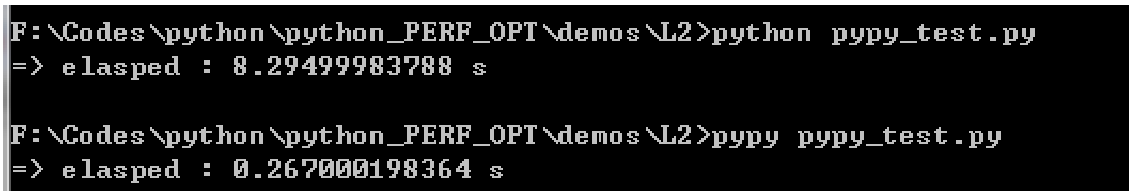
不是一个Python模块，而是另一个Python解释器
http://pypy.org/download.html

- 使用

```
python xxx.py
pypy xxx.py
```

- 速度测试对比

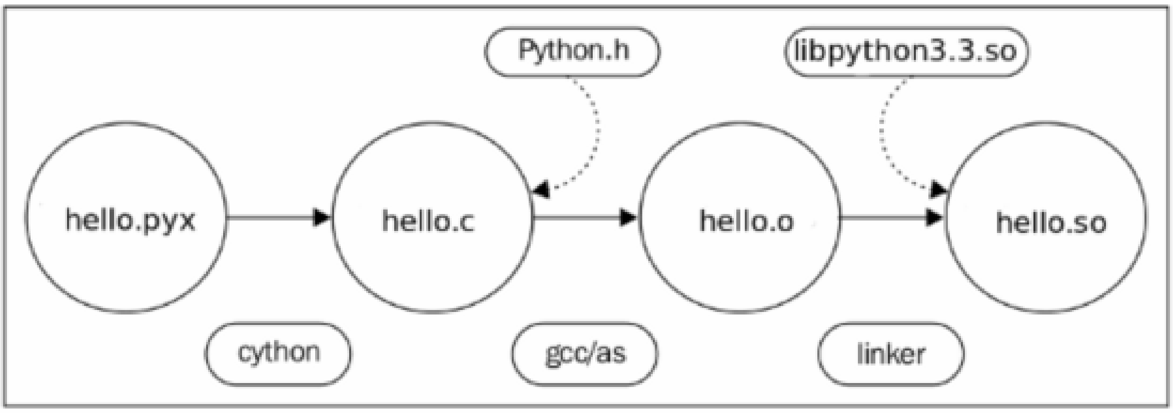
```
#pypy_test.py
from timer import Timer
with Timer() as t:
    for i in xrange(100000):
        rs = 0
        for i in xrange(1000):
            rs += i
print "=> elasped : %s s" % t.secs
```



```
F:\Codes\python\python_PERF_OPT\demos\L2>python pypy_test.py
=> elasped : 8.29499983788 s

F:\Codes\python\python_PERF_OPT\demos\L2>pypy pypy_test.py
=> elasped : 0.267000198364 s
```

3.2 Cython

将Python源代码转换成c语言代码，然后再从c代码编译成2进制程序



- 安装

  http://cython.org/#download

  pip install Cython

- 使用

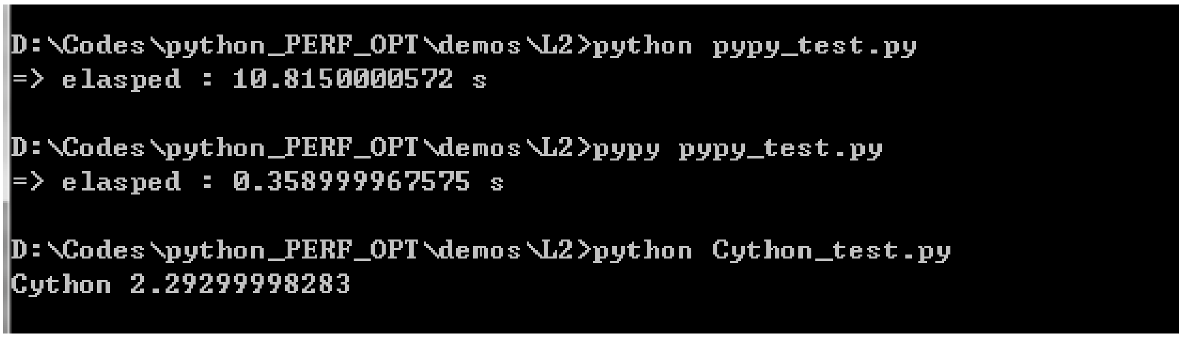
```
#Cython_compute.pyx
def test():
    for i in xrange(100000):
        rs = 0
        for i in xrange(1000):
            rs += i
```

```
#setup.py
from distutils.core import setup
from Cython.Build import cythonize
setup(name = 'Cpython_test app',
      ext_modules = cythonize("Cython_compute.pyx"))
```

```
python setup.py build
#如果windows下build失败，升级python至最新版本，升级setuptools至最新版本，从vs（测试使用vs2012）本地命令行进入，SET VS90COMNTOOLS=%VS110COMNTOOLS%
python setup.py install
```

```python
#Cython_test.py
from timer import Timer
from Cython_compute import *
if __name__ == '__main__':
    with Timer() as t:
        test()
    print "Cython %s"%t.secs
```

- 性能对比



```
D:\Codes\python_PERF_OPT\demos\L2>python pypy_test.py
=> elasped : 10.8150000572 s

D:\Codes\python_PERF_OPT\demos\L2>pypy pypy_test.py
=> elasped : 0.358999967575 s

D:\Codes\python_PERF_OPT\demos\L2>python Cython_test.py
Cython 2.29299998283
```

3.3 没有银弹

通过上面的测试会发现pypy的能力是无与伦比的

但是操作数字的小程序是比较容易被优化

demo测试的结论无法代表实际项目中的效果，实际项目中PyPy和Cython不一定普通的Python会快。

4. 进入Python底层

单纯的从脚本运行方式上下手不是绝对稳妥，但是走向底层绝对不会错。

4.1 ctypes

ctypes库可以让开发者直接进入Python的底层，借助C语言的力量进行开发。这个库只有官方版本解释器（CPython）里面才有，因为这个版本是C语言写的。

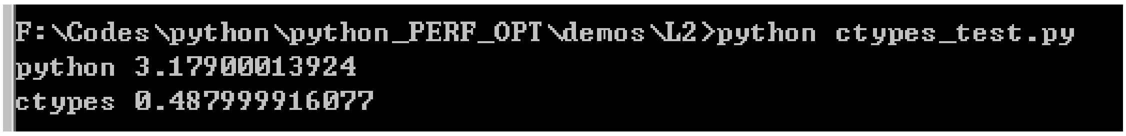
- ### 加载自定义的ctypes

  有时，无论我们在代码上用了多少优化方法，可能都没法儿满足我们对性能的要求。这时我们可以把关键代码写成C语言，编译成一个库，然后导入Python当作模块使用。

```
//dll2ctypes.cpp
int WINAPI c_check_prime(int a)
{
    int c;
    for ( c = 2 ; c <= sqrt((float)a) ; c++ ) {
        if ( a%c == 0 )
            return 0;
    }
    return 1;
}
```

```
#ctypes_test.py
import math
from timer import *
import ctypes

MAX = 1000000
def check_prime(x):
    values = xrange(2, int(math.sqrt(x)))
    for i in values:
        if x % i == 0:
            return False
    return True

c_check_prime =
ctypes.CDLL(r'.\ctypes\dll2ctypes\x64\Release\dll2ctypes.dll').c_check_prime


with Timer() as t:
    numbers_py = [x for x in xrange(MAX) if check_prime(x)]
print "python %s"%t.secs

with Timer() as t:
    numbers_py = [x for x in xrange(MAX) if c_check_prime(x)]
print "ctypes %s"%t.secs
```

- 性能对比结果



```
F:\Codes\python\python_PERF_OPT\demos\L2>python ctypes_test.py
python 3.17900013924
ctypes 0.487999916077
```

4.2 SWIG

SWIG是一种软件开发工具。它能让一些脚本语言调用C/C++语言的接口。

- 安装

下载地址http://www.swig.org/download.html

- 简单例子

```
/* File : example.c */
double  My_variable  = 3.0;
/* Compute factorial of n */
int  fact(int n) {
    if (n <= 1) return 1;
    else return n*fact(n-1);
}
/* Compute n mod m */
int my_mod(int n, int m) {
    return(n % m);
}
```

你想在你的脚本语言的代码里面调用fact函数。先写一段非常简单的SWIG脚本，文件名为example.i：

```
/* File : example.i */
%module example
%{
/* Put headers and other declarations here */
extern double My_variable;
extern int    fact(int);
extern int    my_mod(int n, int m);
%}
extern double My_variable;
extern int    fact(int);
extern int    my_mod(int n, int m);
```

```
#setup.py
from distutils.core import setup, Extension
setup(name='example',
      version='1.0.0',
      description='Simple SWIG example ',
      ext_modules=[Extension('_example', sources=['example.c', 'example.i'])]
      )
```

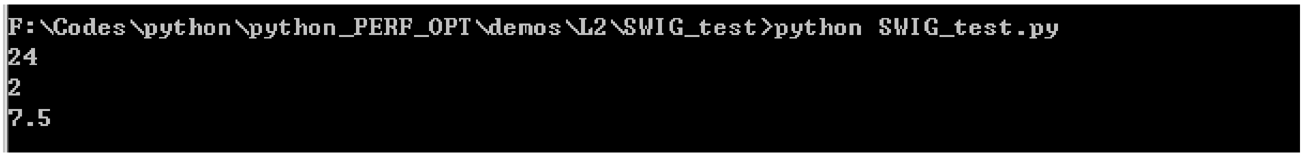
- 编译

  类似之前的Cython编译

```
python setup.py build_ext --inplace
```

- 运行

```python
import example
print example.fact(4)
print example.my_mod(23,7)
print example.cvar.My_variable + 4.5
```



```
F:\Codes\python\python_PERF_OPT\demos\L2\SWIG_test>python SWIG_test.py
24
2
7.5
```