# Tuning Python Applications Can Dramatically Increase Performance

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# Agenda

Why do we need Python optimization?

How one finds the code to tune?

Overview of existing tools

An example

Intel® VTune Amplifier capabilities and comparison

Q & A

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# Why do we need Python optimization?

- Python is used to power wide range of software, including those where application performance matters
- Some Python code may not scale well, but you won't know it unless you give it enough workload to chew on
- Sometimes you are just not happy with the speed of your code

All in all, there are times when you want to make your code run faster, be more responsive, *(insert your favorite buzzword here)*.

So, you need to **optimize** (or tune) your code.

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# How one finds the code to tune – measuring vs guessing

- **Hard stare** = Often wrong

- **Logging** = Analysis is tedious

- **Profile** = Accurate, Easy

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# Not All Profilers Are Equal

There are different profiling techniques, for example:

- **Event-based**
  - Example: built-in Python cProfile profiler

- **Instrumentation-based**
  - Usually requires modifying the target application (source code, compiler support, etc.)
  - Example: line_profiler

- **Statistical**
  - Accurate enough & less intrusive
  - Example: vmstat, statprof

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# Most Profilers – High Overhead, No Line Info

| Tool | Description | Platforms | Profile level | Avg. overhead |
|---|---|---|---|---|
| cProfile (built-in) | • Text interactive mode: “pstats” (built-in)<br>• GUI viewer: RunSnakeRun<br>• Open Source | Any | Function | 1.3x-5x |
| Python Tools | • Visual Studio (2010+)<br>• Open Source | Windows | Function | ~2x |
| PyCharm | • Not free<br>• cProfile/yappi based | Any | Function | 1.3x-5x (same as cProfile) |
| line_profiler | • Pure Python<br>• Open Source<br>• Text-only viewer | Any | Line | Up to 10x or more |

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# Example performance hogs

<table>
<tr><th>Task</th><th>Slow way</th><th>Faster way</th></tr>
<tr><td>Concatenate a list</td><td><pre>s = ''
for ch in some_lst:
    s += ch</pre></td><td><pre>s = ''.join(some_lst)</pre></td></tr>
<tr><td colspan="3" align="center">reason</td></tr>
<tr><td>Remove some value from a list</td><td><pre>while some_value in lst:
    lst.remove(some_value)</pre></td><td><pre>while True:
    try:
        lst.remove(some_value)
    except ValueError:
        break</pre></td></tr>
<tr><td colspan="3" align="center">reason</td></tr>
</table>

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# Python example to profile: **demo.py**

```
class Encoder:
    CHAR_MAP = {'a': 'b', 'b': 'c'}
    def __init__(self, input):
        self.input = input

    def process_slow(self):
        result = ''
        for ch in self.input:
            result += self.CHAR_MAP.get(ch, ch)
        return result

    def process_fast(self):
        result = []
        for ch in self.input:
            result.append(self.CHAR_MAP.get(ch, ch))
        return ''.join(result)
```

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# Python sample to profile: **run.py**

```
import demo
import time

def slow_encode(input):
    return demo.Encoder(input).process_slow()

def fast_encode(input):
    return demo.Encoder(input).process_fast()

if __name__ == '__main__':
    input = 'a' * 10000000 # 10 millions of 'a'
    start = time.time()
    s1 = slow_encode(input)
    slow_stop = time.time()
    print 'slow: %.2f sec' % (slow_stop - start)
    s2 = fast_encode(input)
    print 'fast: %.2f sec' % (time.time() - slow_stop)
```

slow: 9.15 sec = 1.00x
fast: 3.16 sec = 1.00x

No profiling overhead - a baseline for tools' overhead comparison

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# cProfile + pstats UI example

```
> python -m cProfile -o run.prof run.py
> python -m pstats run.prof

run.prof% sort time
run.prof% stats
Tue Jun 30 18:43:53 2015    run.prof

         30000014 function calls in 15.617 seconds

   Ordered by: internal time

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        1    9.597    9.597   10.268   10.268 demo.py:6(process_slow)
        1    3.850    3.850    5.302    5.302 demo.py:12(process_fast)
 20000000    1.267    0.000    1.267    0.000 {method 'get' of 'dict' objects}
 10000000    0.790    0.000    0.790    0.000 {method 'append' of 'list' objects}
        1    0.066    0.066    0.066    0.066 {method 'join' of 'str' objects}
        1    0.038    0.038    5.340    5.340 run.py:7(fast_encode)
        1    0.009    0.009   15.617   15.617 run.py:1(<module>)
        1    0.000    0.000   10.268   10.268 run.py:4(slow_encode)
```

slow: 10.27 sec = 1.12x
fast: 5.34 sec = 1.69x



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# cProfile + RunSnakeRun

Run Snake Run: run.prof

File View View Type

Percent functions

| Name | Calls | RC... | Local | /Call |
|---|---|---|---|---|
| process_slow | 1 | 1 | 7.91... | 7.91.. |
| process_fast | 1 | 1 | 3.82... | 3.82.. |
| <method 'get' of 'dict' objects> | 2000... | 20... | 1.16... | 0.00.. |
| <method 'append' of 'list' objects> | 1000... | 10... | 0.70... | 0.00.. |
| fast_encode | 1 | 1 | 0.10... | 0.10.. |
| <method 'join' of 'str' objects> | 1 | 1 | 0.07... | 0.07.. |
| <module> | 1 | 1 | 0.00... | 0.00.. |
| slow_encode | 1 | 1 | 0.00... | 0.00.. |
| <module> | 1 | 1 | 0.00... | 0.00.. |
| __init__ | 2 | 2 | 0.00... | 0.00.. |
| Encoder | 1 | 1 | 0.00... | 0.00.. |
| <method 'disable' of '_lsprof.Profiler' objects> | 1 | 1 | 0.00... | 0.00.. |
| | 0 | 2 | 0.00... | 0.00.. |

process_slow@demo.py:6 [8.515s]

process_fast@demo.py:12 [5.16

<method 'app

<method 'g

Callees | All Callees | Callers | All Callers | Source Code

| Name | Calls | RC... | Local | /Call | Cum | /Call | File | L... | Directory |
|---|---|---|---|---|---|---|---|---|---|
| <met... | 2000... | 20... | 1.16... | 0.00... | 1.16... | 0.00... | ~ | 0 | |

__init__@demo.py:3 [0.000s]

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# cProfile in PyCharm

demo - [C:\Users\ \PycharmProjects\demo] - demo.pstat - PyCharm 4.5.3

File Edit View Navigate Code Refactor Run Tools VCS Window Help

demo.pstat | demo.py | run.py | demo.pstat

Statistics | Call Graph

| Name | Call Count | Time (ms) | | Own Time (ms) | |
|---|---|---|---|---|---|
| process_slow | 1 | 10069 | 64.2% | 9423 | 60.1% |
| process_fast | 1 | 5560 | 35.5% | 4036 | 25.7% |
| <method 'get' of 'dict' objects> | 20000000 | 1272 | 8.1% | 1272 | 8.1% |
| <method 'append' of 'list' object | 10000000 | 831 | 5.3% | 831 | 5.3% |
| <method 'join' of 'str' objects> | 1 | 65 | 0.4% | 65 | 0.4% |
| fast_encode | 1 | 5601 | 35.7% | 40 | 0.3% |
| run.py | 1 | 15678 | 100.0% | 7 | 0.0% |
| slow_encode | 1 | 10069 | 64.2% | 0 | 0.0% |
| <time.time> | 3 | 0 | 0.0% | 0 | 0.0% |
| demo.py | 1 | 0 | 0.0% | 0 | 0.0% |
| __init__ | 2 | 0 | 0.0% | 0 | 0.0% |
| Encoder | 1 | 0 | 0.0% | 0 | 0.0% |

Run

```
C:\Python27\python.exe "C:\Program Files (x86)\JetBrains\PyCharm 4.5.3\helpers\profiler\run_profiler.py" 127.0.0.1 49605 C:/U:
Starting cProfile profiler

slow: 10.07 sec
fast: 5.60 sec
Snapshot saved to C:\Users\ \.PyCharm40\system\snapshots\demo.pstat
```

...ons on Java 7 if firewall is enabled. Command netsh advfirewall set... (5 minutes ago)

slow: 10.07 sec = 1.10x
fast: 5.60 sec = 1.77x

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# line_profiler results

```
Total time: 18.095 s
File: demo_lp.py
Function: process_slow at line 6
Line #      Hits     Time  Per Hit   % Time  Line Contents
==========================================================
     6                                       @profile
     7                                       def process_slow(self):
     8         1       14     14.0      0.0      result = ''
     9  10000001 10260548      1.0     23.3      for ch in self.input:
    10  10000000 33814644      3.4     76.7          result += self.CHAR_MAP.get(...
    11         1        4      4.0      0.0      return result

Total time: 16.8512 s
File: demo_lp.py
Function: process_fast at line 13
Line #      Hits     Time  Per Hit   % Time  Line Contents
==========================================================
    13                                       @profile
    14                                       def process_fast(self):
    15         1        7      7.0      0.0      result = []
    16  10000001 13684785      1.4     33.3      for ch in self.input:
    17  10000000 27048146      2.7     65.9          result.append(self.CHAR_MAP.get(...
    18         1   312611 312611.0      0.8      return ''.join(result)
```

slow: 24.32 sec = 2.66x
fast: 25.37 sec = 8.03x

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# Python Tools GUI example

Performance_20150630(2).vsp - Microsoft Visual Studio

FILE EDIT VIEW PROJECT DEBUG TEAM TOOLS TEST ANALYZE WINDOW HELP

Performance_20150630(2).vsp | Performance_20150630.vsp | Performance_20150630(1).vsp | demo.py

Current View: Summary

**Instrumentation Profiling Report**

28.3 seconds of total execution time

Note:
Wallclock time (not CPU)

**Hot Path**

| Function Name | Elapsed Inclusive Time % | Elapsed Exclusive Time % |
|---|---|---|
| python.exe | 100.00 | 0.00 |
| run (module) | 100.00 | 0.07 |
| **run.slow_encode** | **60.13** | **0.00** |
| **run.fast_encode** | **39.79** | **0.00** |

Related Views: Call Tree Functions

**Functions With Most Individual Work**

| Name | Exclusive Time % |
|---|---|
| demo.Encoder.process_slow | 56.49 |
| demo.Encoder.process_fast | 26.94 |
| dict.get | 9.12 |
| list.append | 7.00 |
| str.join | 0.39 |

Report
- Show Trimmed Ca
- Compare Reports
- Export Report Dat
- Save Analyzed Re
- Filter Report Data
- Toggle Full Screer
- Set Symbol Paths

slow: 17.40 sec = 1.90x
fast: 12.08 sec = 3.82x

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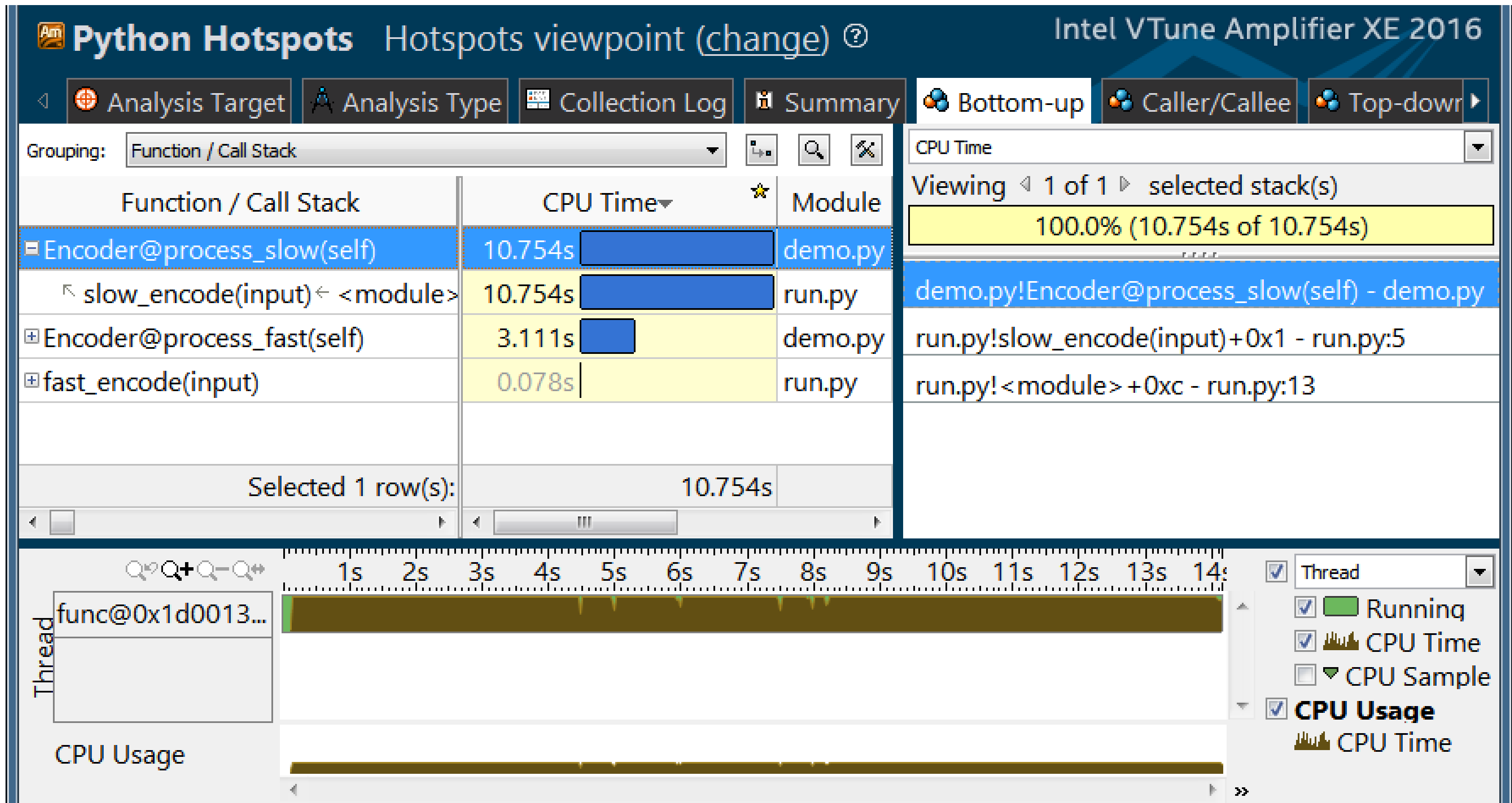
# Intel® VTune Amplifier example




slow: 10.85 sec = 1.19x
fast: 3.30 sec = 1.05x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# Intel® VTune Amplifier – source view

Python Hotspots Hotspots viewpoint (change) Intel VTune Amplifier XE 2016

Summary | Bottom-up | Caller/Callee | Top-down Tree | Platform | demo.py

Source | Assembly | Assembly grouping: Address

| S. | Source | CPU Time |
|---|---|---|
| 1 | class Encoder: | |
| 2 | CHAR_MAP = {'a': 'b', 'b': 'c'} | |
| 3 | def __init__(self, input): | |
| 4 | self.input = input | |
| 5 | | |
| 6 | def process_slow(self): | |
| 7 | result = '' | |
| 8 | for ch in self.input: | |
| 9 | result += self.CHAR_MAP.. | 10.754s |
| 10 | return result | |
| 11 | | |
| 12 | def process_fast(self): | |
| 13 | result = [] | |

CPU Time

Viewing 1 of 1 selected stac

100.0% (10.754s of 10.754s)

demo.py!Encod...lf) - demo.py

run.py!slow_en...0x1 - run.py:5

run.py!<modul...c - run.py:13



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# Intel® VTune Amplifier: Accurate & Easy

## Line-level profiling details:

- Uses sampling profiling technique
- Average overhead ~1.1x-1.6x (on certain benchmarks)

## Cross-platform:

- Windows and Linux
- Python 32- and 64-bit; 2.7.x, 3.4.x, 3.5.0 versions

## Rich Graphical UI

## Supported workflows:

- Start application, wait for it to finish
- Attach to application, profile for a bit, detach

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# Low Overhead *and* Line-Level Info

| Tool | Description | Platforms | Profile level | Avg. overhead |
|---|---|---|---|---|
| Intel® VTune Amplifier | • Rich GUI viewer | Windows<br>Linux | Line | ~1.1-1.6x |
| cProfile (built-in) | • Text interactive mode: “pstats” (built-in)<br>• GUI viewer: RunSnakeRun (Open Source)<br>• PyCharm | Any | Function | 1.3x-5x |
| Python Tools | • Visual Studio (2010+)<br>• Open Source | Windows | Function | ~2x |
| line_profiler | • Pure Python<br>• Open Source<br>• Text-only viewer | Any | Line | Up to<br>10x or more |

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# We’ve Had Success Tuning Our Python Code

- One widely-used web page in our internally set up Buildbot service: 3x speed up (from 90 seconds to 28)
- Report generator – from 350 sec to <2 sec for 1MB log file
  - Distilled version was the base for demo.py
- Internal SCons-based build system: several places sped up 2x or more
  - Loading all configs from scratch tuned from 6 minutes to 3 minutes

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# Q & A

… and again:

- For Tech Preview and Beta, drop us an email at scripting@intel.com
- Check out free Intel® software – just google for "free intel tools" to see if you're qualified

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<tr><td>Academic Researcher+</td><td><u>Intel® Performance Libraries</u><br>Intel® Math Kernel Library<br>Intel® MPI Library<br>Intel® Threading Building Blocks<br>Intel® Integrated Performance Primitives</td><td rowspan="4">Forum only support</td><td rowspan="4">Free!</td></tr>
<tr><td>Student+</td><td rowspan="2">Intel® Parallel Studio XE Cluster Edition</td></tr>
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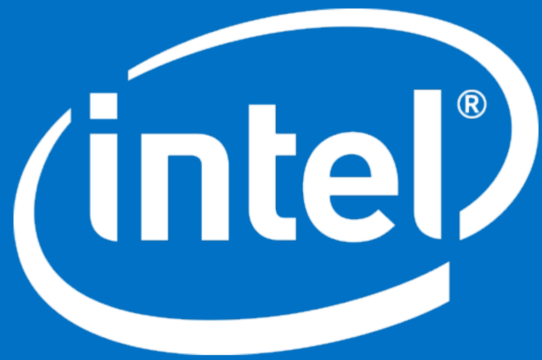
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