

Performance Implications of Programming Languages

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Final Report

Northeastern University
EECE 5640

In 2020, I did a co-op at Purefacts Financial Solutions in our machine learning R&D team. One problem we spent a lot of time talking about was the memory footprint of our algorithm, which was so big that in its first test with a real data set, 64G of ram hadn't been enough and the program didn't work. Because of this we spent a lot of time optimizing our code. And yet the code was in Python, a language well-known for being rather inefficient. We made our program work, but I always wondered how much performance we lost by our choice of programming language.

The question I wanted to answer in my project is a generalization of the above: how much does one's choice of programming language affect performance? Everyone knows that C is faster than Python, but how much faster? And where do other languages fit in?

Specifically, I measured the following languages:

- Python
- C
- Java

Using the following benchmarks:

- Canonical Matrix Multiplication
- Optimized Matrix Multiplication
- Sorting (via standard library)
- Heap (measured by sorting a list)

Performance was measured by the following metrics:

- Runtime (wall-clock)
- Peak memory usage

All source code used in this project is available on [GitHub](#).

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1 Testing Methodology

I evaluated each language over a series of benchmarks intended to represent a variety of general-purpose yet performance-intensive computing workloads.

The source code of all benchmarks are publically available on [GitHub](#), along with instructions describing how to run them.

1.1 Choice of Benchmarks

1.1.1 Canonical Matrix Multiplication

Matrix multiplication is a common benchmark in high-performance computing and is a useful task in many applications. It's memory-intensive but has somewhat good caching performance due to the storage of data in 2d arrays.

I implemented this multiplication myself, based on the following psuedocode:

```
1  matmul(matrix a, matrix b, matrix c) {
2      for (i = 0; i < N; i++) {
3          for (j = 0; j < N; j++) {
4              c[i][j] = 0;
5              for (k = 0; k < N; k++) {
6                  c[i][j] += a[i][k] * b[k][j];
7              }
8          }
9      }
10 }
```

No manual optimizations were applied, but C code was compiled with `-O3`.

1.1.2 Optimized Matrix Multiplication

In addition to seeing what a language can do in typical use, I was also interested in what it can do when it has been optimized to the highest extent possible. I again used matrix multiplication for this benchmark, since it's common enough to have highly-optimized libraries in each language I used. Specifically:

Python Numpy

C OpenBLAS

Java EJML

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1.1.3 Sorting

Another common task in software is sorting a list. This is a performance-intensive task, and is included in the standard libraries of each language I am evaluating. This allowed me to evaluate the efficiency of standard library functions (as opposed to 3rd-party libraries evaluated in matrix multiplication).

1.1.4 Heap

The above benchmarks all use data organized in arrays. Arrays are good for caching since they have high spatial locality. But I was also interested in what happens when operating on a pointer-heavy data structure, where closely related blocks of data may be far apart in physical memory address. I did this by implementing a heap as a binary tree.

To exercise this data structure, I sorted a list. I generated a list of floats, inserted each into the heap, then popped them all into a new list.

1.2 Data Extraction

There were two data points collected for every benchmark: runtime and peak memory usage. Runtime was measured directly by the language under test. Memory usage was measured using Valgrind's Massif tool.

In both cases benchmarks were managed—and data collected—using a Python script. Another Python script generated graphs for analysis.

2 Results

2.1 Canonical Matrix Multiplication

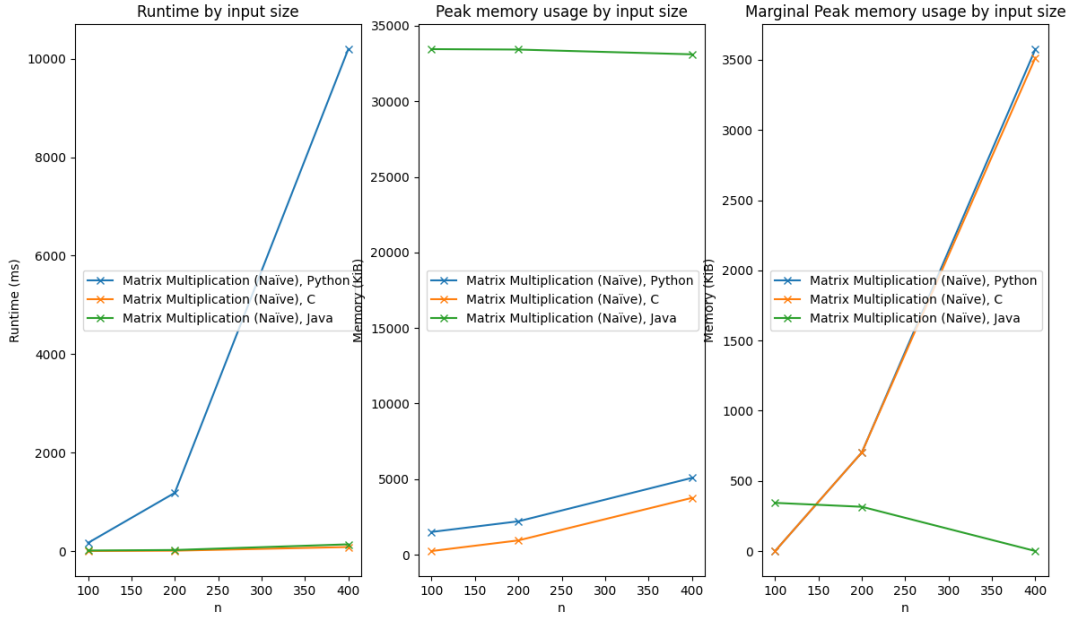


Figure 1: Performance of canonical matrix multiplication.

Figure 1 shows the performance of canonical matrix multiplication. The leftmost graph shows the runtime of the benchmark. This *only* measures the benchmark itself, not any setup or tear-down. In this case, runtime includes multiplying two matrices, but not allocating the input matrices and filling them with random data.

The center graph shows peak memory usage, measured using Valgrind. This measurement includes the entire benchmark program, including both setup and tear-down. This is because there is no good way in Valgrind to determine what part of the program is running at any given time. The rightmost graph shows *marginal* memory usage, which is the peak memory usage minus the lowest peak memory usage of that program and benchmark, for any input. It is intended to show the memory associated with increased input size, without any constant overhead.

C did very well in this benchmark. At all input sizes, it was both the fastest and used the least memory.

Python did very poorly on speed, taking 10 times the runtime as C on larger input sizes. It performed much better on memory. Although Python carried a 1 MB overhead, this overhead

was constant. In marginal memory usage Python was very slightly worse than C. Java on the other hand performed very well in runtime, with runtimes only doubling that of C on larger inputs. Java's limitation was in terms of memory, with performance *considerably* worse than Python or C. This memory usage was an overhead. Java's marginal memory usage appears very good, but that is probably due to random variance in the memory overhead making the marginal memory usage an invalid measurement.

2.2 Heap

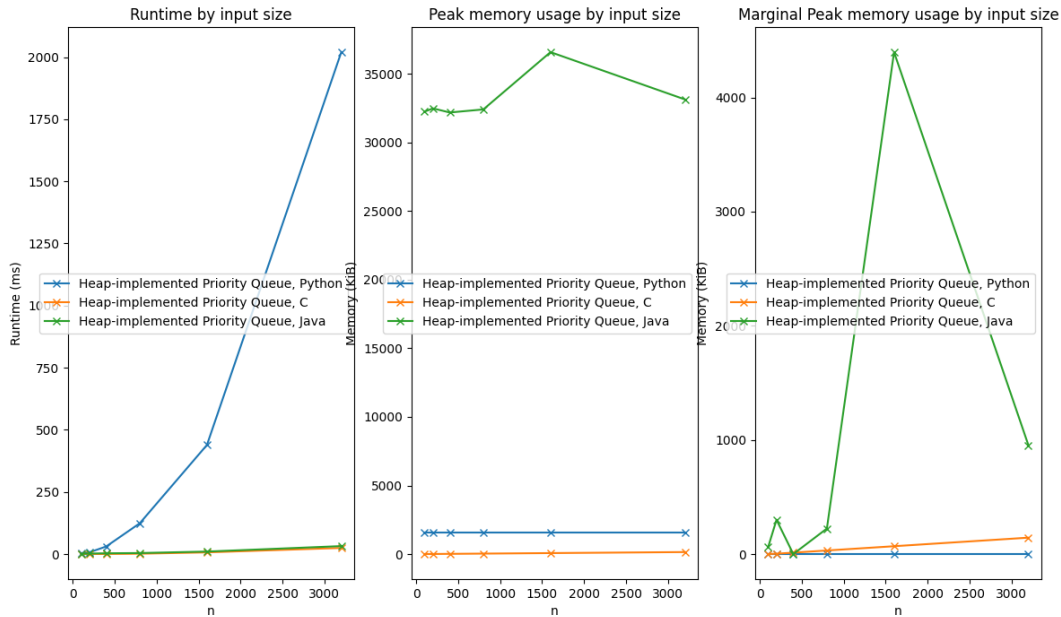


Figure 2: Performance of a heap.

Figure 2 shows the performance of my heap implementation. As with 2.1 Canonical Matrix Multiplication, C's performance was boring and efficient.

Python's performance was similar to 2.1 Canonical Matrix Multiplication: memory was efficiency, constant overhead notwithstanding, but runtime was very poor.

Java's performance¹ was unremarkable. Like previously, it is roughly comparable to C.

¹Java's results for this benchmark are different that what I presented in class on April 22, 2022. I noticed a bug after the presentation where the Java implementation skipped all the computation.

2.3 Standard Library Sorting

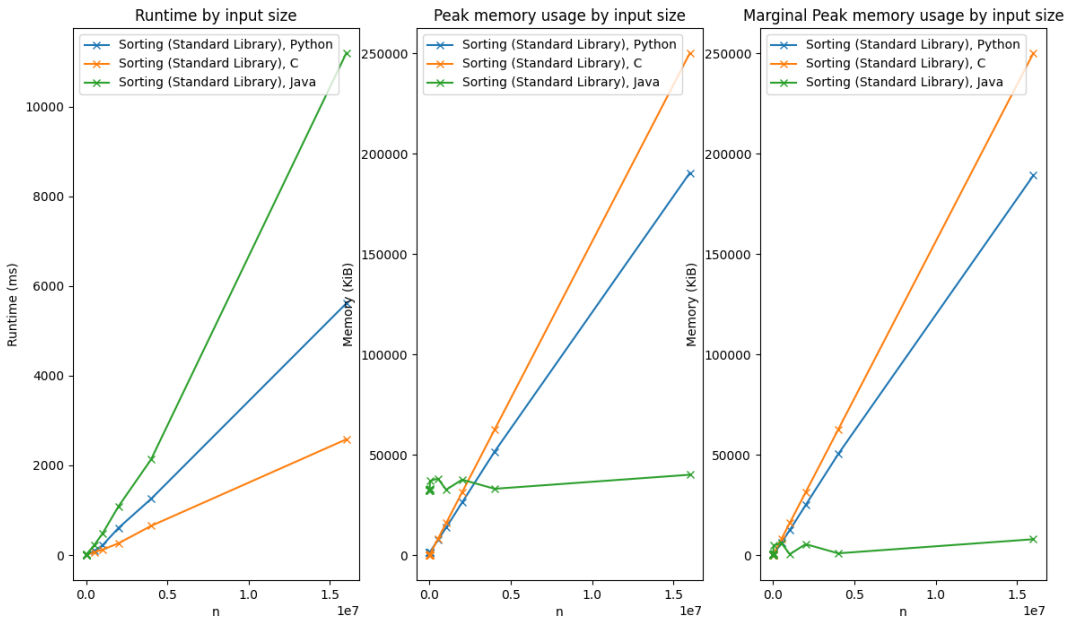


Figure 3: Performance of sorting via standard library functions.

Figure 3 shows the performance of sorting via the various language’s standard library. As usual, C was fast and efficient.

Python’s performance on this benchmark was interesting. The runtime performance was about double that of C. That doesn’t seem impressive—it’s still slower—but in previous benchmarks it was orders of magnitude slower. As usual, Python’s memory performance was quite good. In fact, it was slightly better than C. There are two main reasons for this: firstly, the memory requirements of storing the input are high enough that the constant overhead is not noticable. This is because Python’s sort implementation is in-place², whereas C’s implementation may not be in-place³ and thus require additional heap space.

Java’s runtime performance was similar to how the language behaved previously: worse than C, but not drastically so. It’s memory performance on the other hand was impossibly good, better than the theoretical minimum size of an array of 64-bit floats. This suggests that Valgrind may not accurately measure heap memory in Java programs.

²Per [Python’s documentation](#).

³In the [GNU specification](#).

2.4 Optimized Matrix Multiplication

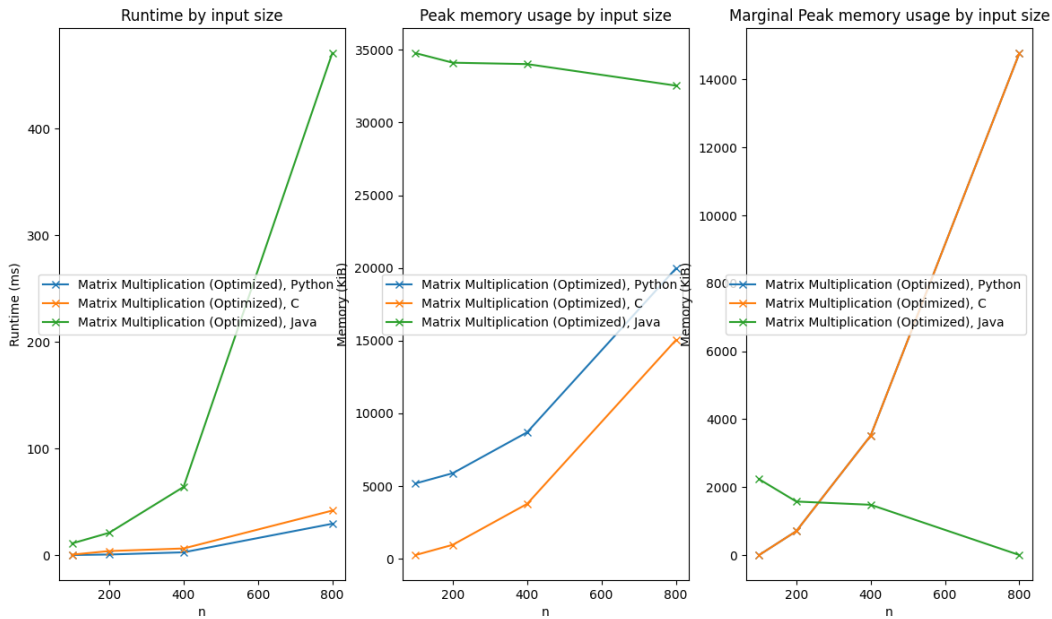


Figure 4: Performance of optimized matrix multiplication.

Figure 4 shows the performance of sorting via heavily-optimized third-party libraries. This benchmark is intended to show what the language can do when it is optimized to the greatest extent possible.

C's matrix multiplication was done using the OpenBLAS⁴ library. As usual, C did reasonably well, but it was *not* the fastest in all cases.

Python used the popular Numpy library, although as discussed in 3.4, this isn't *quite* a correct statement. Impressively, Python's performance at the largest input size was slightly better than C. Its marginal memory performance was also very good, almost exactly equal to that of C⁵.

Java used the EJML linear algebra library. Its performance was unimpressive, with runtimes larger than C, but within the same order of magnitude.

⁴Basic Linear Algebra System

⁵This is why the Python line isn't visible on the marginal memory usage graph: The Python line is exactly underneath the C line.

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3 Analysis

3.1 Why Python is so Slow

Something that's very clear from 2.2 Heap and 2.1 Canonical Matrix Multiplication is that Python code is really, *really* slow.

On a high level, the reasons for this are rather simple. Firstly, C and Java are both ahead-of-time compiled languages: transformation of textual code to computer-friendly bytecode is done before runtime by a compiler, either GCC or the Java Compiler. Python, on the other hand, is a JIT language, or just-in-time compiled. Compilation is done *at* runtime. This adds a time overhead.

Python is also an interpreted language. C's bytecode is run directly on the CPU's hardware, with no layer of indirection.⁶ But Python runs in the Python Interpreter, a program that interprets and runs your code for you. Need to reference a variable? Your code has to ask the interpreter to do it for you. Want to call a function? Again, the interpreter adds a (slow) layer in between your code and a function call on the CPU. All this adds up to a significant slowdown.

Python isn't the only interpreted language in my sample: Java is also interpreted: it runs in the Java Virtual Machine (JVM). But the JVM is more efficient than the Python Interpreter, probably because it's a thinner abstraction.

3.2 Java Memory Overhead

It's very apparent from all benchmarks that before allocating *any* significant data, Java has a large memory overhead, consistently about 30 MB. This is because of the JVM. As it turns out, the JVM has to store a lot of data about the code itself: compiled classes, field names and function signatures, as well as the garbage collector. In particular, compressed class space grows proportionally to the number of classes loaded⁷, and can easily dwarf the heap. For more information, see [Memory footprint of the JVM](#), an article by Spring Blog that delves into this topic in some detail. For my purposes, the main takeaway is that every Java process that gets launched will immediately take up 30 MB of RAM.

The question I'm more interested in is this: is this a significant loss of available memory? Well, it depends. Certainly it's problematic in embedded applications where available memory is sometimes measured in bytes. But Java is not commonly used for embedded tasks. Java is normally run on modern machines like telephones and computers, where gigabytes of memory are available. Suppose an application is being developed that will run on a server with 128 GB of ram available. Is this 30 MB overhead significant? Again, it depends. If the deployment plan is to run a handful of processes that each do a lot of work, the memory

⁶Except for the indirection built into CPU itself, but that is common to all programs.

⁷Which in turn is roughly proportional to the complexity of your code.

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overhead probably isn't significant. If the plan is to run microservices, with thousands of process each doing a tiny piece of work, then this tiny overhead is now taking up gigabytes of memory, and that probably *is* a problem.

3.3 Why Sorting in Python *isn't* Terrible

As noted in 3.1, Python is rather painfully slow. Except, in 2.3 Sorting⁸, it isn't. Why? Because the sorting isn't done in Python code. It's done directly by the Python Interpreter. Or, to be more precise, it's done by the CPython interpreter, since CPython is the Python implementation under test. CPython is implemented in C. So Python's sorting is implemented in C^{9,10} which, as this project has made abundantly clear, is quite fast.

So speaking generally, what are the implications of this? It means that although Python code runs slowly, standard library functions run quite quickly. So will a performance-intensive application run in a reasonable time in Python? It depends. If most of the computation happens within a standard library function, it might run quite quickly.

3.4 Why Python's Numpy is Fast

So far, we've established that Python code is very slow, but Python standard library functions can be fast, though not *as* fast as C. So one would expect that Python's optimized matrix multiplication runs very slowly. It's certainly not a standard library function. And yet, Numpy's performance was approximately the same as C, both in terms of runtime and in terms of marginal memory usage.

How is this possible? Well, Python (or, at least, the popular CPython implementation) has a rarely-used but enormously powerful feature: it can interface nicely with C and C++ code¹¹. This means that a Python program with a performance-intensive component can implement that component in C, taking advantage of C's efficiency. This is exactly how Numpy implements matrix multiplication: in C. In fact, it uses OpenBLAS. Most of the work in the Python matrix multiplication benchmark happens in a call to `cblas_dgemm`, the exact same function used in my C benchmark. So of *course* Python's performance was similar to C's: on some level, it was running exactly the same code.

⁸It also wasn't slow in 2.4. I'll address this in 3.4.

⁹For reference, see [the header sorting where sorting is declared](#) and [the implementation](#).

¹⁰Presumably, if I tested Jython, it would be implemented in Java.

¹¹[Extending Python with C or C++](#)

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4 Conclusion

Before starting this project, I had a vague idea that C was very efficient and Python was very slow, with most languages in the middle. In other words, to program in a easy-to-use language like Python, you have to pay the price of worse performance. My goal in this project was to quantify this cost, with the ultimate goal of helping answer the question of whether that cost is worth it.

To absolutely no one's surprise, the answer is that *it depends*.

The performance penalty will depend not only on what language is used, but also on *how* that language is used. Python is the most extreme example of this. A pure-Python implementation might be very slow. But what if an application is 90 % Python, 10 % C? If the performance-intensive part is in C, you can sort of get the best of both worlds: most of your code is built in the easy-to-use Python, but code that has to run fast is built in the more efficient C.

Ultimately, every language will have advantages and disadvantages. To intelligently choose the best language for a particular task, one needs to know what these advantages and disadvantages are. To that end, here are listed the specific, objective results of this project:

- The runtime of Python code can be over 100 times the runtime of equivalent C code.
- The runtime of Java code is generally about double the runtime of equivalent C code.
- Each Python process introduces a memory overhead of approximately 100 kB.
- Each Java process introduces a memory overhead of approximately 30 MB.
- The memory overhead of loading a small C program is negligible for most purposes.
- The marginal cost of allocating more data in Python is not materially different than allocating equivalent data in C.
- The marginal cost of allocating more data in Java is difficult to measure.
- Python standard library functions can be nearly as fast or as fast as their C equivalents. The same is true of third-party libraries that have implemented some of their functionality in C.
- CPython allows easy integration with C code, meaning that a Python codebase can, in some cases, be easily accelerated by implementing a small portion of the codebase in C.

A Computer Specifications

These benchmarks can be run on any AMD-64 computer. Since runtimes are only compared to each other, running on different computers shouldn't meaningfully affect results. Additionally, since all benchmarks are single-threaded, the number of available cores shouldn't affect performance.

However, the specifications of the test machine are listed below, collected using Inxi via `inxi --admin --verbosity=7 --filter`.

```

1 System:
2   Kernel: 5.13.0-37-generic x86_64 bits: 64 compiler: N/A
3   parameters: BOOT_IMAGE=/@/boot/vmlinuz-5.13.0-37-generic
4   root=UUID=4b08d9d7-9ad0-4036-b964-208d6ae91032 ro rootflags=subvol=@ quiet
5   splash
6   Desktop: Cinnamon 5.0.7 wm: muffin 5.0.2 dm: LightDM 1.30.0
7   Distro: Linux Mint 20.2 Uma base: Ubuntu 20.04 focal
8 Machine:
9   Type: Laptop System: Razer
10  product: Blade 15 Advanced Model (Early 2020) - RZ09-033 v: 5.04
11  serial: <filter> Chassis: type: 10 serial: <filter>
12  Mobo: Razer model: CH551 v: 4 serial: <filter> UEFI: Razer v: 1.01
13  date: 04/16/2020
14 Battery:
15  ID-1: BAT0 charge: 81.3 Wh condition: 81.3/80.2 Wh (101%) volts: 15.8/15.4
16  model: Razer Blade type: Unknown serial: <filter> status: Full
17  Device-1: hidpp_battery_23 model: Logitech Wireless Mouse MX Master 3
18  serial: <filter> charge: 55% (should be ignored) rechargeable: yes
19  status: Discharging
20 Memory:
21  RAM: total: 15.53 GiB used: 11.89 GiB (76.6%)
22  RAM Report: permissions: Unable to run dmidecode. Root privileges required.
23 CPU:
24  Topology: 8-Core model: Intel Core i7-10875H bits: 64 type: MT MCP arch: N/A
25  family: 6 model-id: A5 (165) stepping: 2 microcode: EA L2 cache: 16.0 MiB
26  bogomips: 73598
27  Speed: 4084 MHz min/max: 800/5100 MHz Core speeds (MHz): 1: 4034 2: 3750
28  3: 3989 4: 3809 5: 3881 6: 3897 7: 3776 8: 967 9: 2679 10: 1270 11: 2852
29  12: 4201 13: 4475 14: 4330 15: 3172 16: 2983
30  Flags: 3dnowprefetch abm acpi adx aes aperfmperf apic arat arch_capabilities
31  arch_perfmon art avx avx2 bmi1 bmi2 bts clflush clflushopt cmov constant_tsc
32  cpuid cpuid_fault cx16 cx8 de ds_cpl dtes64 dtherm dts epb ept ept_ad erms
33  est f16c flexpriority flush_l1d fma fpu fsgsbase fxsr ht hwp hwp_act_window
34  hwp_epp hwp_notify ibpb ibrs ibrs_enhanced ida intel_pt invpcid
35  invpcid_single lahf_lm lm mca mce md_clear mmx monitor movbe mpx msr mtrr
36  nonstop_tsc nopl nx ospke pae pat pbe pcid pclmulqdq pdcu pdep1gb pebs pge
37  pku pln pni popcnt pse pse36 pts rdrand rdseed rdtscp rep_good sdbg sep smap
38  smep smx ss ssbd sse sse2 sse4_1 sse4_2 ssse3 stibp syscall tm tm2
39  tpr_shadow tsc tsc_adjust tsc_deadline_timer vme vmx vnmi vpid x2apic
40  xgetbv1 xsave xsavec xsaveopt xsaves xtopology xtprr

```

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```
41 Vulnerabilities: Type: itlb_multihit status: KVM: VMX disabled
42 Type: l1tf status: Not affected
43 Type: mds status: Not affected
44 Type: meltdown status: Not affected
45 Type: spec_store_bypass
46 mitigation: Speculative Store Bypass disabled via prctl and seccomp
47 Type: spectre_v1
48 mitigation: usercopy/swapgs barriers and __user pointer sanitization
49 Type: spectre_v2 mitigation: Enhanced IBRS, IBPB: conditional, RSB filling
50 Type: srbds status: Not affected
51 Type: tsx_async_abort status: Not affected
52 Graphics:
53 Device-1: NVIDIA vendor: Razer USA driver: nvidia v: 510.47.03
54 bus ID: 01:00.0 chip ID: 10de:1e93
55 Display: x11 server: X.Org 1.20.13 driver: nvidia
56 resolution: 1920x1080~60Hz, 1920x1080~240Hz
57 OpenGL: renderer: llvmpipe (LLVM 12.0.0 256 bits) v: 4.5 Mesa 21.2.6
58 compat-v: 3.1 direct render: Yes
59 Audio:
60 Device-1: Intel Comet Lake PCH cAVS vendor: Razer USA driver: snd_hda_intel
61 v: kernel bus ID: 00:1f.3 chip ID: 8086:06c8
62 Device-2: NVIDIA TU104 HD Audio vendor: Razer USA driver: snd_hda_intel
63 v: kernel bus ID: 01:00.1 chip ID: 10de:10f8
64 Sound Server: ALSA v: k5.13.0-37-generic
65 Network:
66 Device-1: Intel Wi-Fi 6 AX201 driver: iwlwifi v: kernel bus ID: 00:14.3
67 chip ID: 8086:06f0
68 IF: wlo1 state: up mac: <filter>
69 IP v4: <filter> type: dynamic noprefixroute scope: global
70 broadcast: <filter>
71 IF-ID-1: gpd0 state: down mac: N/A
72 IF-ID-2: tun0 state: unknown speed: 10 Mbps duplex: full mac: N/A
73 IP v4: <filter> scope: global
74 WAN IP: <filter>
75 Drives:
76 Local Storage: total: 953.87 GiB used: 313.23 GiB (32.8%)
77 SMART Message: Required tool smartctl not installed. Check --recommends
78 ID-1: /dev/nvme0n1 vendor: LITE-ON model: CA5-8D1024 size: 953.87 GiB
79 block size: physical: 512 B logical: 512 B speed: 31.6 Gb/s lanes: 4
80 serial: <filter> rev: CQA0901 scheme: GPT
81 Message: No Optical or Floppy data was found.
82 RAID:
83 Message: No RAID data was found.
84 Partition:
85 ID-1: / raw size: 46.57 GiB size: 102.45 GiB (220.00%)
86 used: 53.92 GiB (52.6%) fs: btrfs dev: /dev/nvme0n1p9 label: N/A
87 uuid: 4b08d9d7-9ad0-4036-b964-208d6ae91032
88 ID-2: /boot/efi raw size: 100.0 MiB size: 96.0 MiB (96.00%)
89 used: 30.2 MiB (31.5%) fs: vfat dev: /dev/nvme0n1p2 label: SYSTEM
90 uuid: 0EA5-BB51
```

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```
91 ID-3: /home raw size: 139.70 GiB size: 383.24 GiB (274.34%)
92 used: 246.31 GiB (64.3%) fs: btrfs dev: /dev/nvme0n1p8 label: N/A
93 uuid: 933a0fe4-8eaa-4cd1-82d1-e723b7872a8d
94 ID-4: /run/timeshift/backup raw size: 46.57 GiB size: 102.45 GiB (220.00%)
95 used: 53.92 GiB (52.6%) fs: btrfs dev: /dev/nvme0n1p9 label: N/A
96 uuid: 4b08d9d7-9ad0-4036-b964-208d6ae91032
97 ID-5: /snap/anbox/186 raw size: 373.8 MiB size: <superuser/root required>
98 used: <superuser/root required> fs: squashfs dev: /dev/loop0 label: N/A
99 uuid: N/A
100 ID-6: /snap/authy/8 raw size: 64.6 MiB size: <superuser/root required>
101 used: <superuser/root required> fs: squashfs dev: /dev/loop1 label: N/A
102 uuid: N/A
103 ID-7: /snap/authy/9 raw size: 64.6 MiB size: <superuser/root required>
104 used: <superuser/root required> fs: squashfs dev: /dev/loop6 label: N/A
105 uuid: N/A
106 ID-8: /snap/bare/5 raw size: 4 KiB size: <superuser/root required>
107 used: <superuser/root required> fs: squashfs dev: /dev/loop15 label: N/A
108 uuid: N/A
109 ID-9: /snap/blender/2090 raw size: 215.4 MiB size: <superuser/root required>
110 used: <superuser/root required> fs: squashfs dev: /dev/loop11 label: N/A
111 uuid: N/A
112 ID-10: /snap/blender/2106 raw size: 215.4 MiB
113 size: <superuser/root required> used: <superuser/root required> fs: squashfs
114 dev: /dev/loop14 label: N/A uuid: N/A
115 ID-11: /snap/core/12834 raw size: 110.6 MiB size: <superuser/root required>
116 used: <superuser/root required> fs: squashfs dev: /dev/loop7 label: N/A
117 uuid: N/A
118 ID-12: /snap/core/12941 raw size: 111.6 MiB size: <superuser/root required>
119 used: <superuser/root required> fs: squashfs dev: /dev/loop2 label: N/A
120 uuid: N/A
121 ID-13: /snap/core18/2284 raw size: 55.5 MiB size: <superuser/root required>
122 used: <superuser/root required> fs: squashfs dev: /dev/loop4 label: N/A
123 uuid: N/A
124 ID-14: /snap/core18/2344 raw size: 55.5 MiB size: <superuser/root required>
125 used: <superuser/root required> fs: squashfs dev: /dev/loop19 label: N/A
126 uuid: N/A
127 ID-15: /snap/gnome-3-28-1804/145 raw size: 162.9 MiB
128 size: <superuser/root required> used: <superuser/root required> fs: squashfs
129 dev: /dev/loop9 label: N/A uuid: N/A
130 ID-16: /snap/gnome-3-28-1804/161 raw size: 164.8 MiB
131 size: <superuser/root required> used: <superuser/root required> fs: squashfs
132 dev: /dev/loop5 label: N/A uuid: N/A
133 ID-17: /snap/gnome-3-34-1804/77 raw size: 219.0 MiB
134 size: <superuser/root required> used: <superuser/root required> fs: squashfs
135 dev: /dev/loop16 label: N/A uuid: N/A
136 ID-18: /snap/gtk-common-themes/1515 raw size: 65.1 MiB
137 size: <superuser/root required> used: <superuser/root required> fs: squashfs
138 dev: /dev/loop13 label: N/A uuid: N/A
139 ID-19: /snap/gtk-common-themes/1519 raw size: 65.2 MiB
140 size: <superuser/root required> used: <superuser/root required> fs: squashfs
```

```

141 dev: /dev/loop12 label: N/A uuid: N/A
142 ID-20: /snap/hello-world/29 raw size: 20 KiB size: <superuser/root required>
143 used: <superuser/root required> fs: squashfs dev: /dev/loop3 label: N/A
144 uuid: N/A
145 ID-21: /snap/nordpass/130 raw size: 75.2 MiB size: <superuser/root required>
146 used: <superuser/root required> fs: squashfs dev: /dev/loop20 label: N/A
147 uuid: N/A
148 ID-22: /snap/nordpass/131 raw size: 76.5 MiB size: <superuser/root required>
149 used: <superuser/root required> fs: squashfs dev: /dev/loop18 label: N/A
150 uuid: N/A
151 ID-23: /snap/slack/60 raw size: 94.9 MiB size: <superuser/root required>
152 used: <superuser/root required> fs: squashfs dev: /dev/loop21 label: N/A
153 uuid: N/A
154 ID-24: /snap/slack/61 raw size: 103.1 MiB size: <superuser/root required>
155 used: <superuser/root required> fs: squashfs dev: /dev/loop17 label: N/A
156 uuid: N/A
157 ID-25: /snap/spotify/58 raw size: 169.6 MiB size: <superuser/root required>
158 used: <superuser/root required> fs: squashfs dev: /dev/loop10 label: N/A
159 uuid: N/A
160 ID-26: /snap/spotify/60 raw size: 169.4 MiB size: <superuser/root required>
161 used: <superuser/root required> fs: squashfs dev: /dev/loop23 label: N/A
162 uuid: N/A
163 ID-27: /tmp raw size: 46.57 GiB size: 45.58 GiB (97.89%)
164 used: 405.9 MiB (0.9%) fs: ext4 dev: /dev/nvme0n1p7 label: N/A
165 uuid: a27a7500-ed82-4d93-ad1d-1525b9dcf578
166 ID-28: swap-1 size: 29.80 GiB used: 12.57 GiB (42.2%) fs: swap
167 swappiness: 60 (default) cache pressure: 100 (default) dev: /dev/nvme0n1p12
168 label: swap1 uuid: 5ee4d08d-45a6-4399-99c0-017ee9a7528e
169 Unmounted:
170 ID-1: /dev/nvme0n1p1 size: 100.0 MiB fs: ntfs label: RazerRecPar
171 uuid: 2484A35584A3286E
172 ID-2: /dev/nvme0n1p10 size: 1000.0 MiB fs: ntfs label: Winre
173 uuid: FC30B63B30B5FCA8
174 ID-3: /dev/nvme0n1p11 size: 103.85 GiB fs: btrfs label: N/A
175 uuid: 933a0fe4-8eaa-4cd1-82d1-e723b7872a8d
176 ID-4: /dev/nvme0n1p3 size: 16.0 MiB fs: <superuser/root required> label: N/A
177 uuid: N/A
178 ID-5: /dev/nvme0n1p4 size: 390.62 GiB fs: ntfs label: Windows-primary
179 uuid: 8C5CB5AB5CB59086
180 ID-6: /dev/nvme0n1p5 size: 55.88 GiB fs: btrfs label: N/A
181 uuid: 4b08d9d7-9ad0-4036-b964-208d6ae91032
182 ID-7: /dev/nvme0n1p6 size: 139.70 GiB fs: btrfs label: N/A
183 uuid: 933a0fe4-8eaa-4cd1-82d1-e723b7872a8d
184 USB:
185 Hub: 1-0:1 info: Full speed (or root) Hub ports: 16 rev: 2.0 speed: 480 Mb/s
186 chip ID: 1d6b:0002
187 Device-1: 1-1:2
188 info: Corsair CORSAIR K95 RGB PLATINUM XT Mechanical Gaming Keyboard
189 type: Keyboard,HID,Mouse driver: hid-generic,usbhid interfaces: 4 rev: 2.0
190 speed: 12 Mb/s chip ID: 1b1c:1b89 serial: <filter>

```

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```
191 Device-2: 1-7:3 info: IMC Networks Integrated Camera type: Video
192 driver: uvcvideo interfaces: 4 rev: 2.0 speed: 480 Mb/s chip ID: 13d3:56d5
193 serial: <filter>
194 Device-3: 1-8:4 info: Razer USA Razer Blade type: Keyboard,Mouse
195 driver: hid-generic,usbhid interfaces: 3 rev: 2.0 speed: 12 Mb/s
196 chip ID: 1532:0253
197 Device-4: 1-14:5 info: Intel type: Bluetooth driver: btusb interfaces: 2
198 rev: 2.0 speed: 12 Mb/s chip ID: 8087:0026
199 Hub: 2-0:1 info: Full speed (or root) Hub ports: 8 rev: 3.1 speed: 10 Gb/s
200 chip ID: 1d6b:0003
201 Hub: 3-0:1 info: Full speed (or root) Hub ports: 2 rev: 2.0 speed: 480 Mb/s
202 chip ID: 1d6b:0002
203 Hub: 4-0:1 info: Full speed (or root) Hub ports: 4 rev: 3.1 speed: 10 Gb/s
204 chip ID: 1d6b:0003
205 Hub: 5-0:1 info: Full speed (or root) Hub ports: 2 rev: 2.0 speed: 480 Mb/s
206 chip ID: 1d6b:0002
207 Hub: 6-0:1 info: Full speed (or root) Hub ports: 2 rev: 3.1 speed: 10 Gb/s
208 chip ID: 1d6b:0003
209 Sensors:
210 System Temperatures: cpu: 62.0 C mobo: N/A gpu: nvidia temp: 63 C
211 Fan Speeds (RPM): N/A
212 Info:
213 Processes: 693 Uptime: 6d 12h 09m Init: systemd v: 245 runlevel: 5
214 Compilers: gcc: 9.4.0 alt: 8/9 Shell: bash v: 5.0.17 running in: server
215 inxi: 3.0.38
```

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```
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