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LINUX DEBUGGING TOOLS you'll ♡

A SMALL wizard tool HANDBOOK FOR ANYONE WHO WRITES (OR RUNS!!) PROGRAMS ON LINUX COMPUTERS

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Hi! This is me:

Julia Evans
blog: jvns.ca
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and in this zine I want to tell you about

how I got better at debugging

These are 5 ways I've changed how I think about debugging:

- Remember the bug is happening for a logical reason. There's no magic.
- Be confident I can fix it

- Talk to someone

phew

I hope you learned something new.
Thanks for reading ♡

Thanks to my partner Kamal for endless reviews, to the amazing Monica Dinculescu (@notwaldorf) for the cover art, and many others.

If you want to know more – my site has a lot (jvns.ca) and brendangregg.com does too.

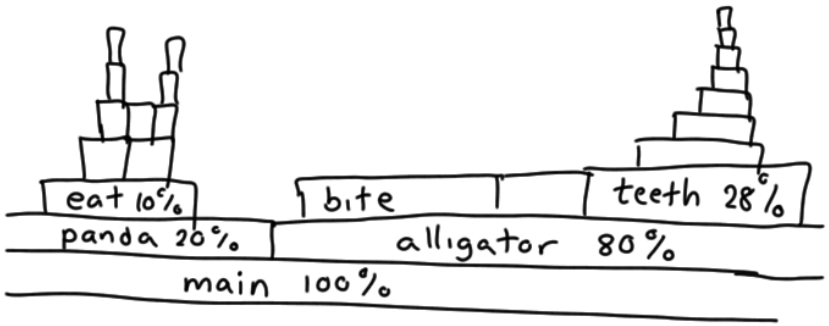
But really you just need to experiment. Try these tools everywhere. See where they help and where they don't. It takes a lot of practice to use these tools to debug real problems.

I've been learning them for 2 years, and I've gotten pretty far, but there's a long way to go. It's really fun

flamegraphs

Flamegraphs are an awesome way to visualize CPU performance, popularized by Brendan Gregg's Flamegraph.pl tool.

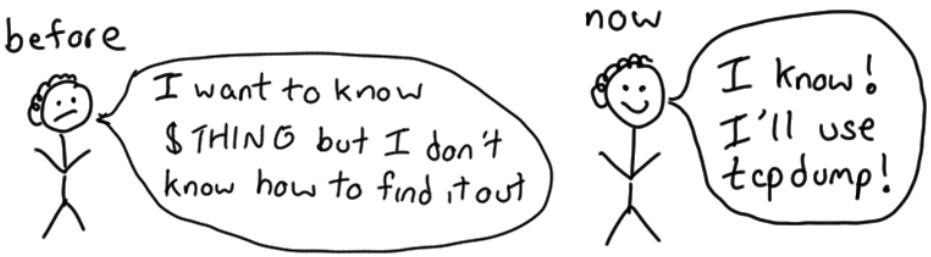
Here's what they look like:



They're constructed from collections (usually thousands) of stack traces sampled from a program. This one above means 80% of the stack traces started with "main alligator ..." and 10% with "main panda eat ..."

You can construct them from perf recordings (look up "Brendan Gregg flamegraph" for how), but lots of other unrelated tools can produce them too. I ♡ them.

Know my debugging toolkit



most importantly: I learned to like it ☺

what you'll learn

I can't teach you in 20 pages to be confident or to ♡ (I'll try anyway) debugging. I can show you some of my {debugging toolkit}: the tools I reach for when I have a question about what my programs are doing. I hope at the end to have given you 1-2 new microscopes to use.

Section 1: I/O and ✲ system calls ✲

Hello, dear reader! In this zine, there are 3 sections of tools that I love.

For each tool, I'll tell you why it's useful and give an example. Each one is either

LINUX ONLY or OS X too!

Some of the most basic questions you might have when you log into a misbehaving machine are:

- is this machine writing to or reading from disk? The network?
- are the programs reading files? Which files?

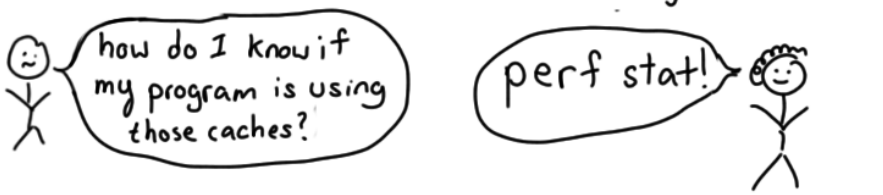
So, we're starting with finding out which resources are being used and what our programs are doing. Let's go!

spy on your CPU!

Your CPU has a small cache on it (the L1 cache) that it can access in ~0.5 nanoseconds! (200 times faster than RAM!)

* tip: google "Latency Numbers every programmer should know"!

If you're trying to do an operation in microseconds, CPU cache usage matters!



how to use it

```
perf stat -e L1-dcache-load-misses ls
```

This runs 'ls' and prints a report at the end.

how it works

Your CPU can keep all kinds of counters about what it's doing. `perf stat` asks it to count things + then collects the result.

Hardware is cool. Knowing more about how your hardware works can really pay off ✲

perf is for everyone

One day, I had a server that was using 100% of its CPU. Within about 60 seconds, I knew it was doing regular expression matching in Ruby. How?

```
$ sudo perf top

process   PID    %    function
ruby      1957   77   match-at
```

perf top doesn't always help. Far from it. But it's an easy tool to try, and it's awesome when it does help.

Ruby's internal regexp matching function

... especially Java and node devs!

Remember when I said perf only knows C functions? It's not quite true. node.js and the JVM (java, scala, clojure...) have both taught perf about their functions.

node

Use the --perf-basic-prof command line option

Java

Look up 'perf-map-agent' on GitHub and follow the directions

dstat

LINUX ONLY

I love dstat because it's super simple. Every second, it prints out how much network and disk your computer used that second.

Once I had an intermittently slow database server. I opened up dstat and stared at the output while monitoring database speed.

```
$ dstat
 send | recv
    0
   3k   } during this period,
   5k   } everything is normal
    0
300 MB  } DATABASE
 48 MB  } GETS SLOW
    0
    0   } back to normal
```

pro dstat tip: the -t flag prints the time every second

Could 300MB coming in over the network mean... a 300MB database query?!

YES.

This was an AWESOME CLUE that helped us isolate the problem query.

strace !!

LINUX ONLY

(I have a strace sticker on my phone)

Strace is my favourite program. It prints every system call your program used. It's a cool way to get an overall picture of what your program is doing, and I ♡ using it to answer questions like "which files are being opened?"

```
$ strace python my_program.py
... hundreds of lines ...
open("/home/bork/.config_file") = 3
read(3, "the contents of the file")
... hundreds of lines ...
connect(5, "172.217.0.163")
sendto(5, "hi!!")
```

(file descriptor)

(read a file!)

(networking!)

strace can make your program run 50x slower. Don't run it on your production database

I can't do justice to strace here, but I have a whole other zine about it at

jvns.ca/zines

♡ perf ♡

perf is not simple or elegant. It is a weird multitool that does a bunch of different, very useful things. First! It's a sampling profiler

Try running:

```
$ sudo perf record python
```

(press Ctrl+C after 2 seconds)

saves a file "perf.data"

This records, every few milliseconds, what the python process is doing. Let's see the results!

```
$ sudo perf report
```

Mine says it spent 5% of its time in the PyDict_GetItem function. Cool! We learned a tiny thing about the CPython interpreter!

just C functions

If you're a Python/Ruby/Java/Node programer, you might be getting antsy. "I want to know which Ruby function is running! Not the C function! Stick with me though. I get you.

works everywhere ♡

perf can be installed on pretty much any Linux machine. The exact features it has will depend a little on your kernel version.

section 3: CPU + perf

LINUX ONLY

Your programs spend a lot of time on the CPU! Billions of cycles. What are they DOING?!

This section is about using perf to answer that question, a Linux-only tool that is extremely useful and not as well-known as it should be :)

(in general, my aim in this zine is to showcase tools that I don't think get enough ♡♡♡)

Some things I didn't have space for in this section but I want to mention anyway:

- valgrind
- the Java ecosystem's fantastic tools (jstack, VisualVM, Mission Control, Yourkit) which your language is probably jealous of
- ftrace (for Linux kernel perf problems)
- eBPF

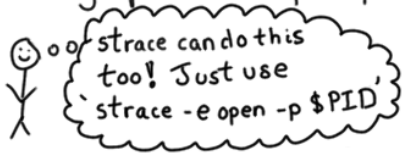
opensnoop! execsnoop! eBPF!

OS X too! (kind of)

When you run

```
opensnoop -p $PID
```

it will print out in real time every file being opened by a program. You might think...



... and you would be right. But strace can make your program run 10x slower. opensnoop won't slow you down. execsnoop tells you what programs are being started.

how to get it

Requires: Ubuntu 16.04+ or a ~4.4+ kernel version

Installation instructions:

github.com/iovisor/bcc-tools

This won't work on many servers today, but keep it in mind! One day you'll have servers running a newer kernel.

how it works

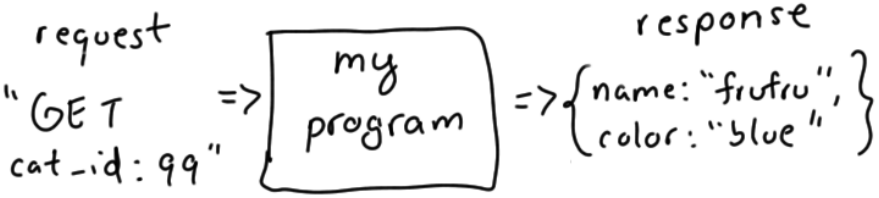
opensnoop is a script that uses a new kernel feature called eBPF. eBPF is fast!

There's also an opensnoop on OS X & BSD! That one is powered by DTrace. eBPF is super powerful. Read Brendan Gregg's blog to learn more!

section 2: networking

I've devoted a lot of space in this zine to networking tools, and I want to explain why.

A lot of the programs I work with communicate over HTTP.



Every programming language uses the same network protocols! So the network is a nice language-independent place to answer questions like:

- was the request wrong, or was it the response?
- is my server even on?
- my program is slow. Whose fault is it?

Let's go!

wireshark

OS X too!

Wireshark is an amazing GUI tool for network analysis. Here's an exercise to learn it! Run this:

```
sudo tcpdump port 80 -w http.pcap
```

While that's running, open metafilter.com in your browser. (or jvns.ca!). Then press Ctrl+C to stop tcpdump. Now we have a pcap!

```
wireshark http.pcap
```

Explore the Wireshark interface!

Questions you can try to answer:

1. What HTTP headers did your browser send to metafilter.com?

   (hint: search `frame contains "GET"`)

2. How long did the longest request take?

   (hint: click Statistics -> Conversations)

3. How many packets were exchanged with metafilter.com's server?

   (hint: search `ip.dst == 54.186.13.33`) — IP address from `ping metafilter.com`

tcpdump

OS X too!

tcpdump is the most difficult networking tool we'll discuss here, and it took me a while to ♡ it. I use it to save network traffic to analyze later!

```
sudo tcpdump port 8997
 -w service.pcap
```

! awesome thing

"port 8997" is actually a tiny program in the "Berkeley Packet Filter" (BPF) language. BPF filters get compiled and they run really fast!

! a "pcap file" ("packet capture") is the standard for saving network traffic. Everything understands pcap♥

Some situations where I'll use tcpdump:

- I'm sending a request to a machine and I want to know whether it's even getting there (`tcpdump port 80` will print every packet on port 80)
- I have some slow network connections and I want to know whether to blame the client or server. (we'll also need wireshark!)
- I just want to print out packets to see them (tcpdump -A)

netcat

handcrafted artisanal networking

OS X too!

HTTP requests are fundamentally really simple — they're just text! To see that, let's make one by hand! First, make a file:

request.txt

```
GET / HTTP/1.1
Host: ask.metafilter.com
User-Agent: zine
(2 newlines! important!!)
```

Then: (nc stands for net cat)

```
$ cat request.txt | nc metafilter.com 80
```

You should get a response back with a bunch of HTML! You can also use netcat to send huge files over a local network quickly:

step 1: (on target machine)

```
$ hostname -I
192.168.2.132 ...

$nc -l 9931 > bigfile
```

this listens on the port!

step 2: (on the source)

```
cat bigfile |
nc 192.168.2.132 9931
```

this sends the data

☆ netstat ☆

OS X too!

Every network request gets sent to a port (like 80) on a computer. To receive a request, a program (aka "server") needs to be "listening" on the port. Finding out which programs are listening on which ports is really easy. It's just

☆ "tuna, please!" ☆

thanks to @icco for the tuna!

also known as

```
sudo netstat -tunapl
```

Here's what you'll see:

proto	local address	PID / program name
tcp	0.0.0.0:5353 (port)	2993 / python

So! I ♡ netstat because it tells me which processes are running on which ports.

On OSX, use `lsof -i -P` instead.

ngrep

OS X too!

grep your network!

ngrep is my favourite starter network spy tool! Try it right now! Run:

```
sudo ngrep -d any metafilter
```

Then go to http://metafilter.com in your browser. You should see matching network packets in ngrep's output! We are SPIES :)

Recently at work I'd made a change to a client so that it sent {"special_id": ...} with all its requests. I wanted to make sure it was working, so I ran

```
sudo ngrep special_id
```

I found out that everything was ok :)