
Thomas Watson
@wa7son
github.com/watson

Agenda

- Introduction to Post-Mortem Debugging
- What are core dumps
- Introduction to llnode
- Debugging crashes
- Debugging unresponsive processes
- Debugging memory leaks

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Node.js Diagnostics Working Group

github.com / nodejs / diagnostics

Post-Mortem Debugging

“*Post-mortem debugging* is debugging of the program after it has already crashed.”

–Wikipedia

Tools

- lldb + llnode
- mdb + mdb_v8
  - autopsy
- node-report => --experimental-report
- node-heapdump => v8.getHeapSnapshot() + v8.writeHeapSnapshot()
- Chrome DevTools


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Core Dumps

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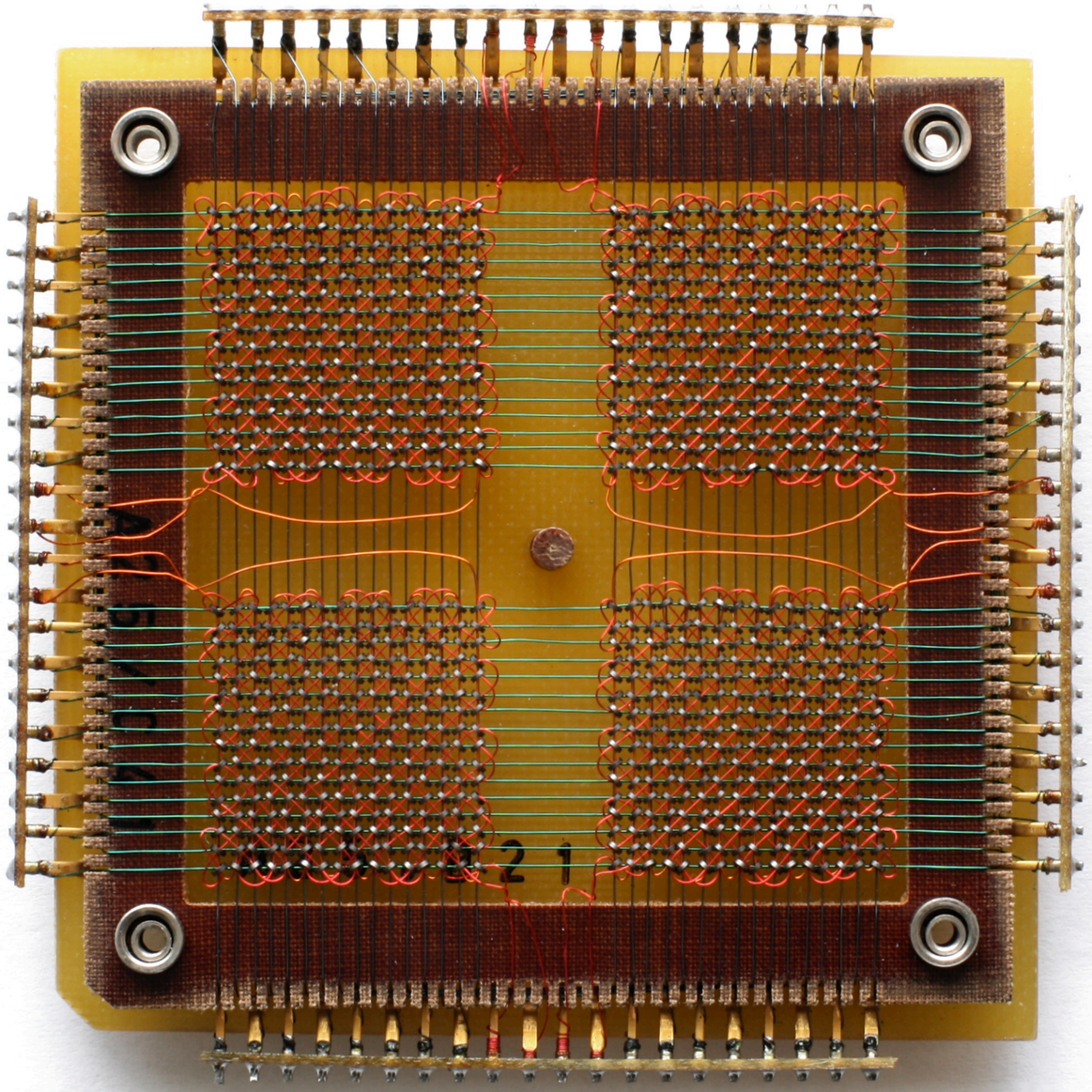

Source: Konstantin Lanzet
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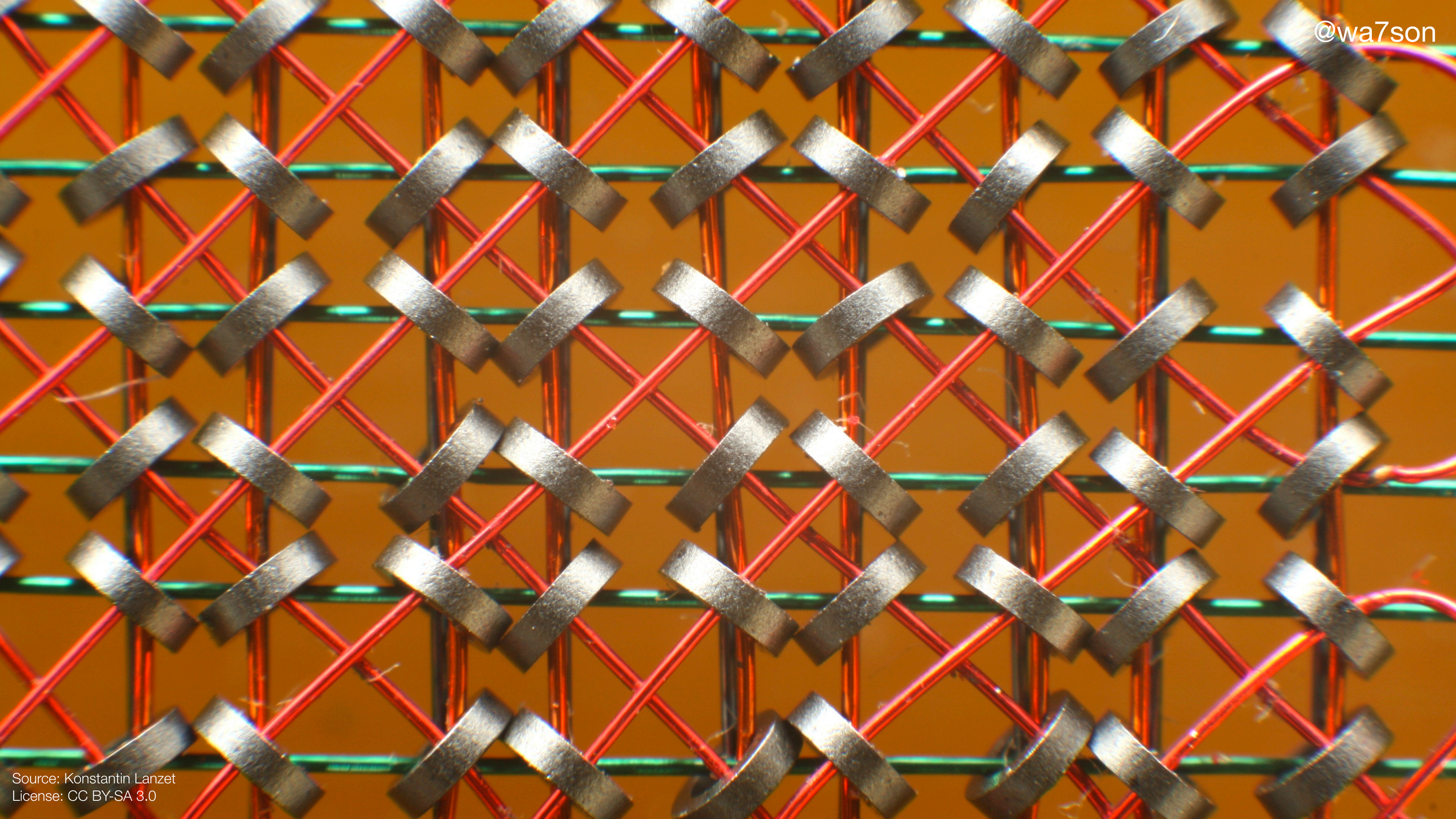
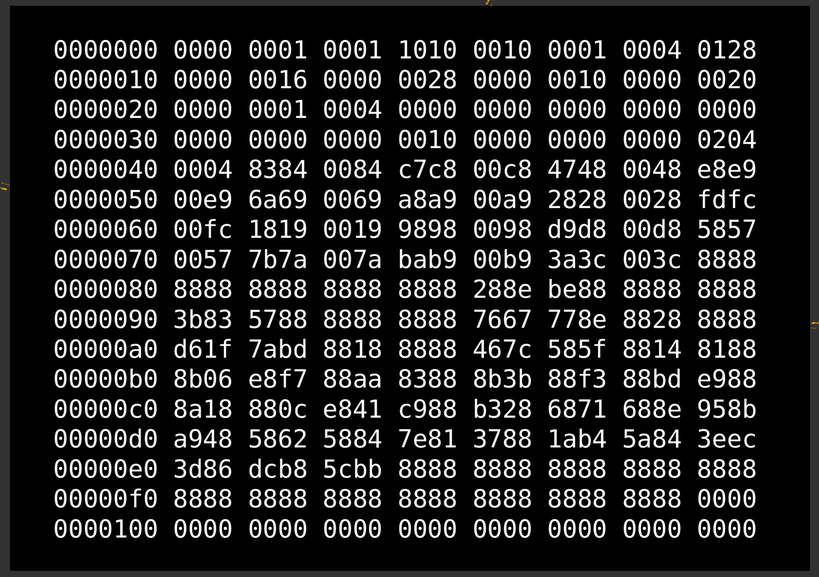


```
0000010 0000 0016 0000 0028 0000 0010 0000 0020
0000020 0000 0001 0004 0000 0000 0000 0000 0000
0000030 0000 0000 0000 0010 0000 0000 0000 0204
0000040 0004 8384 0084 c7c8 00c8 4748 0048 e8e9
0000050 00e9 6a69 0069 a8a9 00a9 2828 0028 fdfc
0000060 00fc 1819 0019 9898 0098 d9d8 00d8 5857
0000070 0057 7b7a 007a bab9 00b9 3a3c 003c 8888
0000080 8888 8888 8888 8888 288e be88 8888 8888
0000090 3b83 5788 8888 8888 7667 778e 8828 8888
00000a0 d61f 7abd 8818 8888 467c 585f 8814 8188
00000b0 8b06 e8f7 88aa 8388 8b3b 88f3 88bd e988
00000c0 8a18 880c e841 c988 b328 6871 688e 958b
00000d0 a948 5862 5884 7e81 3788 1ab4 5a84 3eec
```

Program counter

Processor registers

System flags



```
0000000 0000 0001 0001 1010 0010 0001 0004 0128
0000010 0000 0016 0000 0028 0000 0010 0000 0020
0000020 0000 0001 0004 0000 0000 0000 0000 0000
0000030 0000 0000 0000 0010 0000 0000 0000 0204
0000040 0004 8384 0084 c7c8 00c8 4748 0048 e8e9
0000050 00e9 6a69 0069 a8a9 00a9 2828 0028 fdfc
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00000a0 d61f 7abd 8818 8888 467c 585f 8814 8188
00000b0 8b06 e8f7 88aa 8388 8b3b 88f3 88bd e988
00000c0 8a18 880c e841 c988 b328 6871 688e 958b
00000d0 a948 5862 5884 7e81 3788 1ab4 5a84 3eec
00000e0 3d86 dcb8 5cbb 8888 8888 8888 8888 8888
00000f0 8888 8888 8888 8888 8888 8888 8888 0000
0000100 0000 0000 0000 0000 0000 0000 0000 0000
```

Core Dump Formats

a.out	Older versions of Unix
ELF	Modern Linux, System V, Solaris, and BSD systems
Mach-O	macOS, etc

Generating a Core Dump

```
ulimit -c unlimited
```

Maximum allowed size of core dump

Generating a Core Dump

```
node --abort-on-uncaught-exception app.js
```

Generating a Core Dump

Generate a core dump form a running process on Linux

Generating a Core Dump

Core dump filename

```
lldb --attach-pid <PID> -b -o 'process save-core "core.<PID>"'
```

Generate a core dump form a running process on macOS

Next Step: The Debugger

gdb, lldb, etc

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as in DeBugger, not DataBase

LLDB

MacOS, iOS, Linux, FreeBSD, and Windows

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```
brew install --with-lldb --with-toolchain llvm
```

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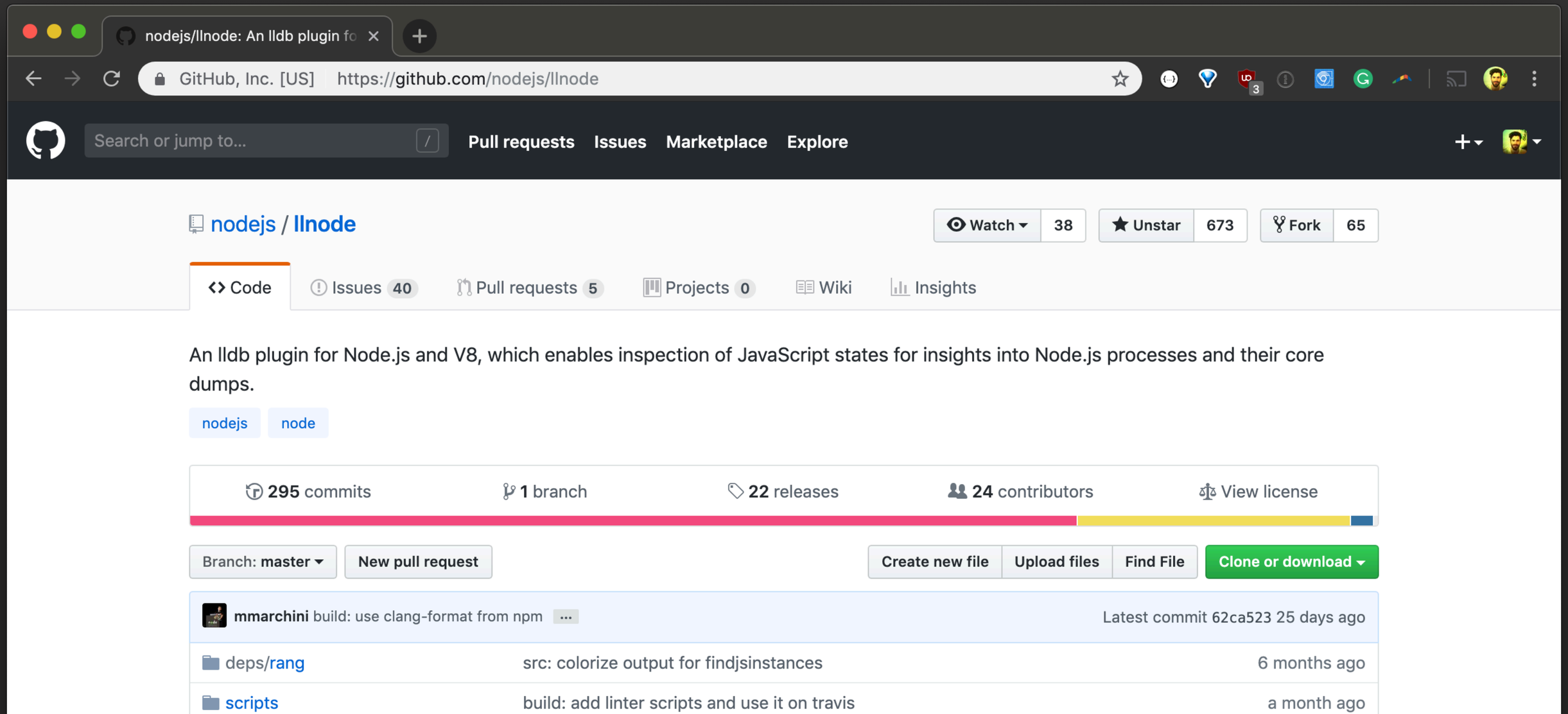
github.com / nodejs / llnode



```
lldb /path/to/program -c /path/to/core-file
```

```
llnode /path/to/node -c /path/to/core-file
```

A problem has been detected and Windows has been shut down to prevent damage to your computer.

The problem seems to be caused by the following file: SPCMDCON.SYS

PAGE_FAULT_IN_NONPAGED_AREA

If this is the first time you've seen this Stop error screen, restart your computer. If this screen appears again, follow these steps:

Check to make sure any new hardware or software is properly installed. If this is a new installation, ask your hardware or software manufacturer for any Windows updates you might need.

If problems continue, disable or remove any newly installed hardware or software. Disable BIOS memory options such as caching or shadowing. If you need to use Safe Mode to remove or disable components, restart your computer, press F8 to select Advanced Startup Options, and then select Safe Mode.

Technical information:

*** STOP: 0x00000050 (0xFD3094C2,0x00000001,0xFBFE7617,0x00000000)

*** SPCMDCON.SYS - Address FBFE7617 base at FBFE5000, DateStamp 3d6dd67c

Crashes

```
Error: boom!
    at /app/server.js:4:13
    at /app/server.js:5:7
    at /app/server.js:6:5
    at processTicksAndRejections (internal/process/task_queues.js:79:9)
    at process.runNextTicks [as _tickCallback] (internal/process/task_queues.js:56:3)
    at Function.Module.runMain (internal/modules/cjs/loader.js:871:11)
    at internal/main/run_main_module.js:21:11
```

```
$ node --abort-on-uncaught-exception server.js
```

```
$ node --abort-on-uncaught-exception server.js
Server is listening on port 3000
```

```
$ node --abort-on-uncaught-exception server.js
Server is listening on port 3000
POST /signup
Uncaught TypeError: Cannot read property 'first' of undefined

FROM
onSave (/app/server.js:16:36)
Timeout._onTimeout (/app/server.js:31:5)
listOnTimeout (internal/timers.js:531:17)
processTimers (internal/timers.js:475:7)
[1]    10904 illegal hardware instruction (core dumped)
  node --abort-on-uncaught-exception server.js
```

```
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processTimers (internal/timers.js:475:7)
[1]    10904 illegal hardware instruction (core dumped)
  node --abort-on-uncaught-exception server.js
```

/cores/core.10904

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$ node --abort-on-uncaught-exception server.js
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[1]    10904 illegal hardware instruction (core dumped)
  node --abort-on-uncaught-exception server.js
```

```
app.post('/signup', function singupRoute (req, res) {
  save(req.body, function onSave (err, user) {
    if (err) return res.status(500).send('Error: ' + err.message)
    res.end('Welcome ' + user.name.first)
  })
})
```

Cannot read property 'first' of undefined

Demo Time!

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Unresponsive Process

What is your program doing right now?

```
const stringify = require('./lib/stringify')

// Turn this:
//   { foo: 1, bar: 2 }
// Into this:
//   { foo: "1", bar: "2" }
console.log(stringify({ foo: 1, bar: 2 }))
```

Demo Time!

Alternative:

CPU Profiling

Recap 1/2

Production Server

- `gcore <pid>`
- `lldb --attach-pid <PID> -b -o 'process save-core "core.<PID>"'`

Recap 2/2

Dev machine

- `llnode node -c core`

llnode

- `v8 help` *Get help*
- `v8 bt` *Get stack trace at crash*
- `frame select 3` *Select stack frame #3*
- `v8 source list` *Show source code at selected stack frame*
- `v8 inspect <addr>` *Inspect object at address*


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Memory Leaks

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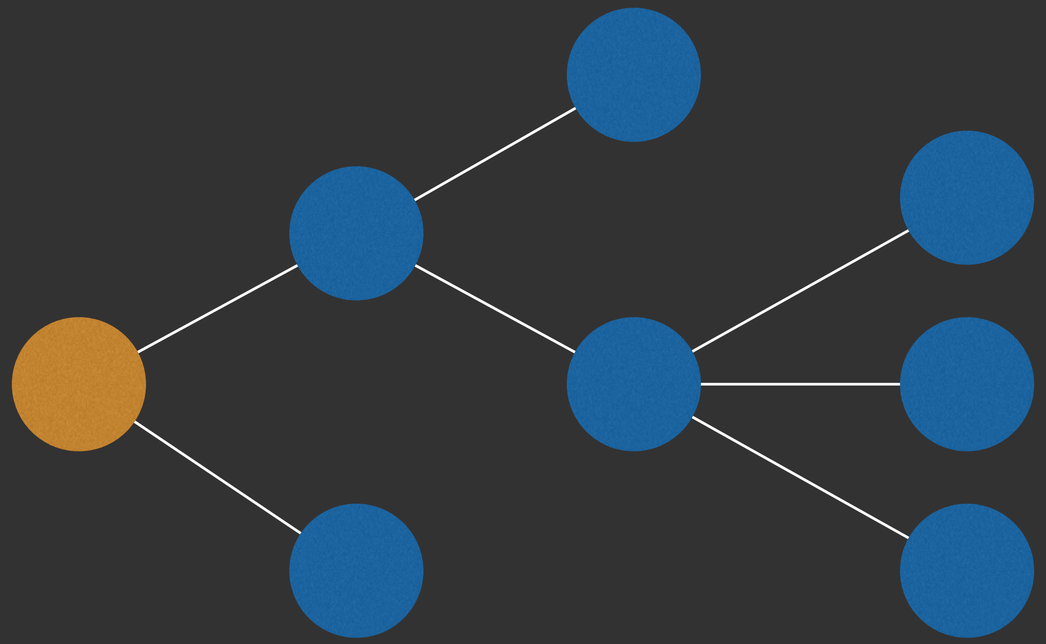
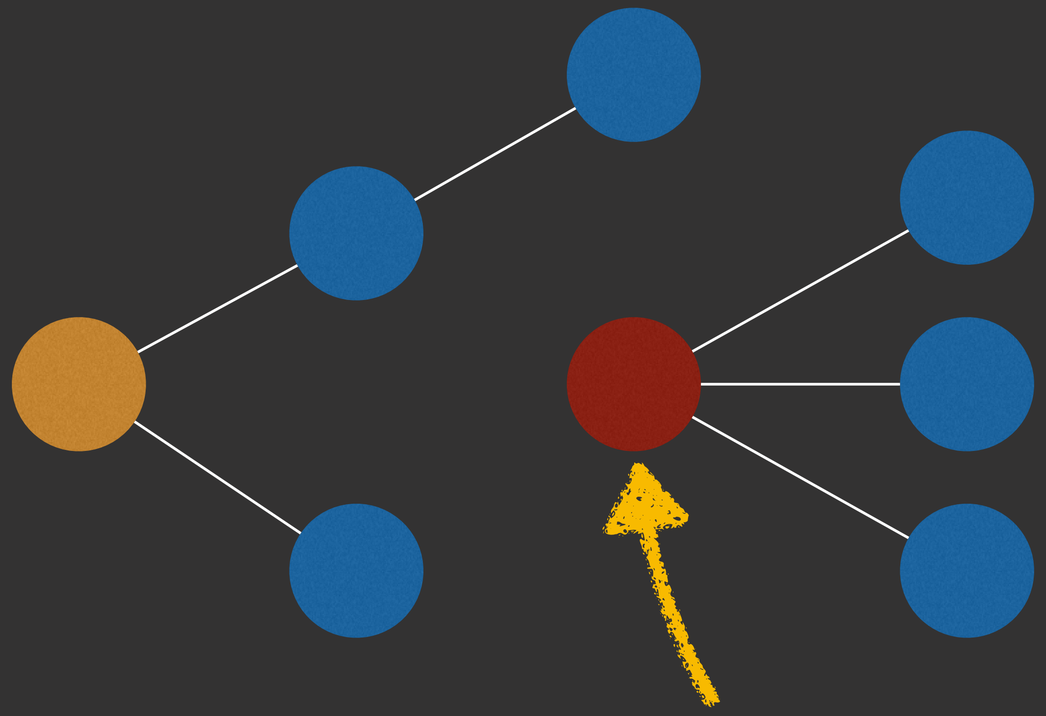
```
FATAL ERROR: CALL_AND_RETRY_2 Allocation failed
- process out of memory Abort trap: 6
```

What are Memory Leaks in JS?

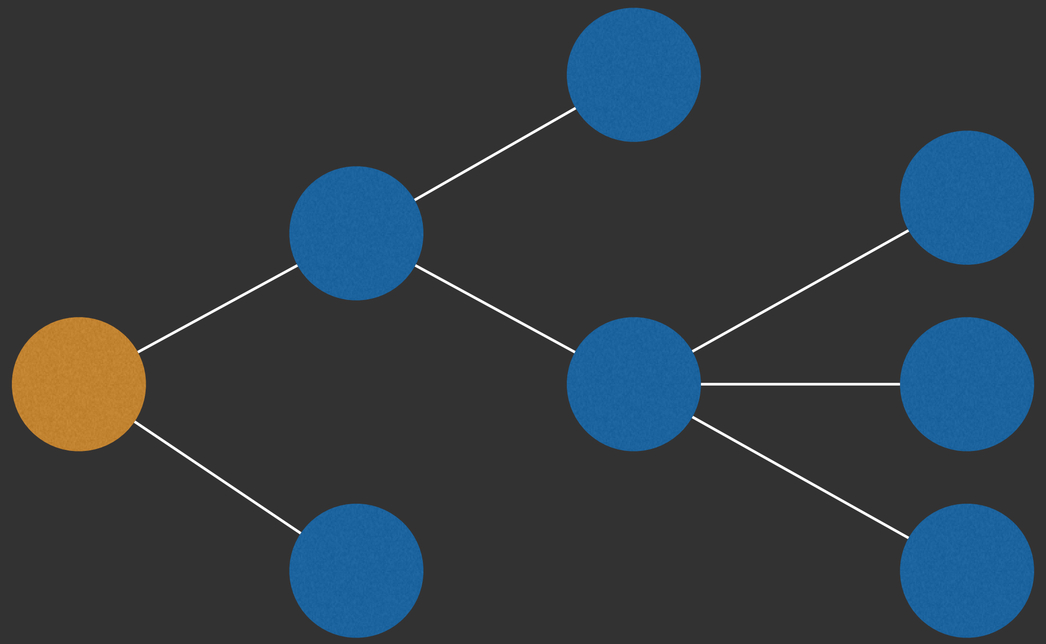


What are Memory Leaks in JS?



No memory leak
(will be garbage collected)

What are Memory Leaks in JS?



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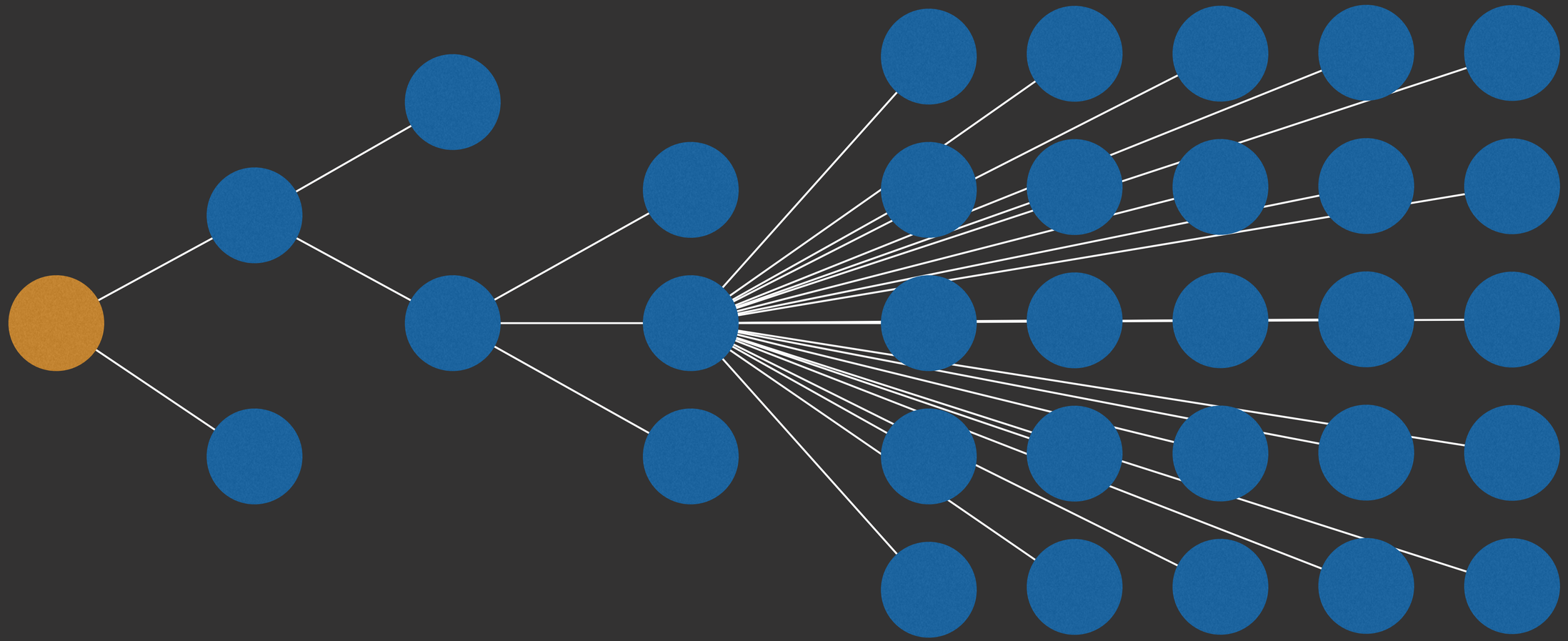
What are Memory Leaks in JS?



```
(llnode) v8 findjsobjects
```

```
(llnode) v8 findjsobjects
 Instances  Total Size Name
 ---------- ---------- ----
          1         24 AssertionError
          1         24 AsyncResource
          1         24 Control
          1         24 FastBuffer
          1         24 Loader
          1         24 ModuleJob
          1         24 ModuleMap
          1         24 Performance
          1         24 PerformanceObserver
          1         24 SafeMap
          1         24 SafePromise
          1         24 SafeSet
          1         24 SocketListReceive
          1         24 SocketListSend
```

```
          12          384 TCP
          12         2688 WritableState
          15         1360 (ArrayBufferView)
          74         4736 NativeModule
        5715      1234440 IncomingMessage
        5744       781184 ServerResponse
        5747      1103424 ReadableState
        5748       275880 BufferList
       45980      2942680 TickObject
       69344      2219008 (Array)
      235515      9420584 Visit
      293720     15437744 Object
      615411      3750984 (String)
---------- ----------
     1283140     37182200
```

```
(llnode) v8 findjsinstances -d Visit
```

```
(llnode) v8 findjsinstances -d Visit
0x0000176d04402201:<Object: Visit properties {
    .visit_id=<Smi: 82704>,
    .headers=0x0000176d7d99f1c9:<Object: Object>}>
0x0000176d04402229:<Object: Visit properties {
    .visit_id=<Smi: 82705>,
    .headers=0x0000176d7d99f191:<Object: Object>}>
0x0000176d04402251:<Object: Visit properties {
    .visit_id=<Smi: 82706>,
    .headers=0x0000176d7d99f159:<Object: Object>}>
0x0000176d04402279:<Object: Visit properties {
    .visit_id=<Smi: 82707>,
    .headers=0x0000176d7d99f121:<Object: Object>}>
0x0000176d044022a1:<Object: Visit properties {
    .visit_id=<Smi: 82708>,
    .headers=0x0000176d7d99f0e9:<Object: Object>}>
0x0000176d044022c9:<Object: Visit properties {
```

```
0x0000176d044022c9:<Object: Visit properties {
    .visit_id=<Smi: 82709>,
    .headers=0x0000176d7d99f0b1:<Object: Object>}>
// A thousand miles later...
0x0000176dffba62d9:<Object: Visit properties {
    .visit_id=<Smi: 156026>,
    .headers=0x0000176dffbef559:<Object: Object>}>
0x0000176dffba6301:<Object: Visit properties {
    .visit_id=<Smi: 156027>,
    .headers=0x0000176dffbef8a9:<Object: Object>}>
0x0000176dffba6329:<Object: Visit properties {
    .visit_id=<Smi: 156028>,
    .headers=0x0000176dffb82481:<Object: Object>}>
```

```
(llnode) v8 inspect -m 0x0000176dffba6329
```

```
(llnode) v8 inspect -m 0x0000176dffba6329
0x0000176dffba6329(map=0x0000176d689cec29):<Object:
  Visit properties {
     .visit_id=<Smi: 156028>,
     .headers=0x0000176dffb82481:<Object: Object>}>
```

```
(llnode) v8 inspect 0x0000176d689cec29
```

```
(llnode) v8 inspect 0x0000176d689cec29
0x0000176d689cec29:<Map own_descriptors=2
  in_object_size=2
  instance_size=40
  descriptors=0x0000176d7f284569:<FixedArray, len=8
contents={
    [0]=<Smi: 2>,
    [1]=<Smi: 0>,
    [2]=0x0000176dd8566a11:<String: "visit_id">,
    [3]=<Smi: 320>,
    [4]=<Smi: 1>,
    [5]=0x0000176dd8566a31:<String: "headers">,
    [6]=<Smi: 1050112>,
    [7]=0x0000176d117509f9:<unknown>}>>
```

```
(llnode) v8 findrefs 0x0000176dffba6329
```

```
(llnode) v8 findrefs 0x0000176dffba6329
0x176d1f4fac41: (Array)[156027]=0x176dffba6329
```

Can this be improved?

- Convert a core dump to a heap snapshot
- Allow user to trigger a gc + heap snapshot from outside the process

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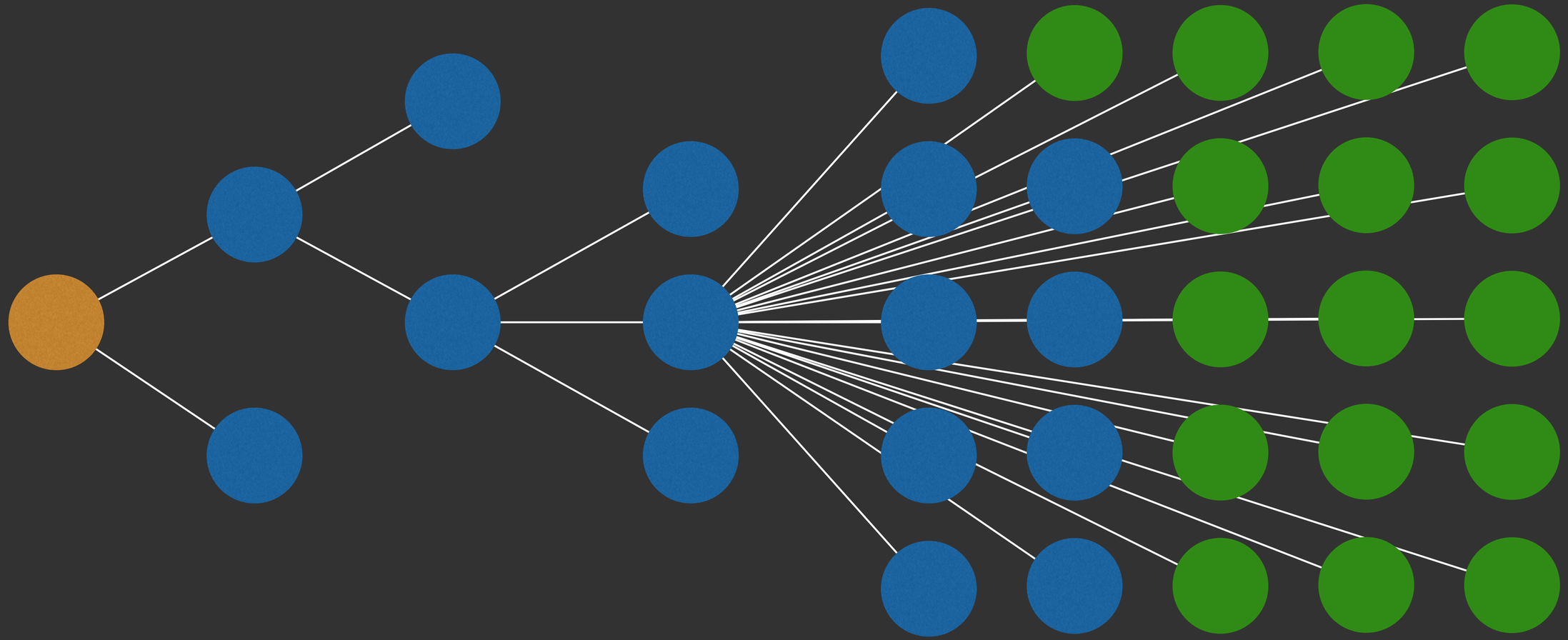
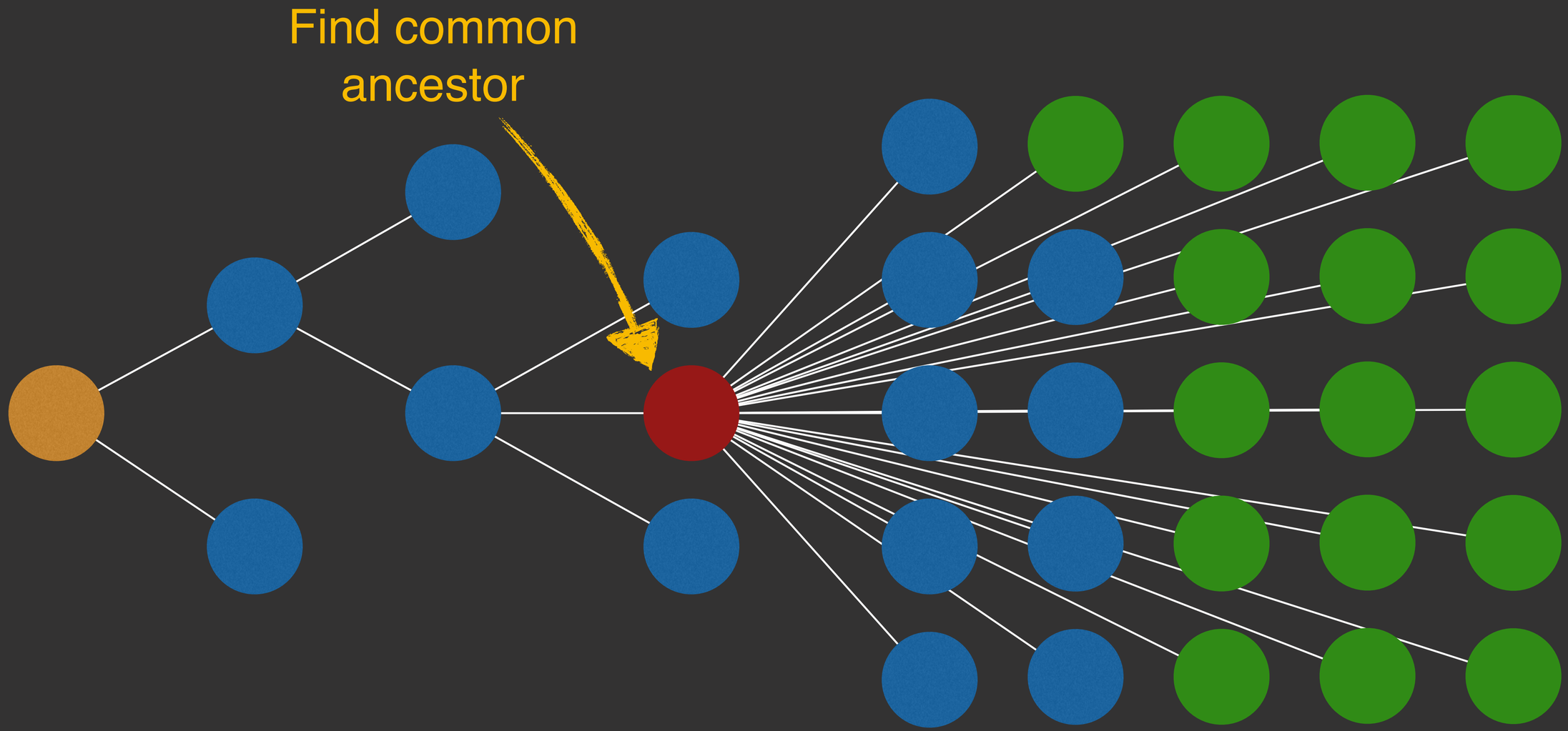
Heap Dump Diffing



Heap Dump Diffing



Writing heap snapshots

kill -SIGUSR2 <pid>

Returns name of file written

```
process.on('SIGUSR2', () => {
  const { writeHeapSnapshot } = require('v8')

  console.log('Heap snapshot written:', writeHeapSnapshot())
})
```

(For now, works only on Node.js 11.13.0+)

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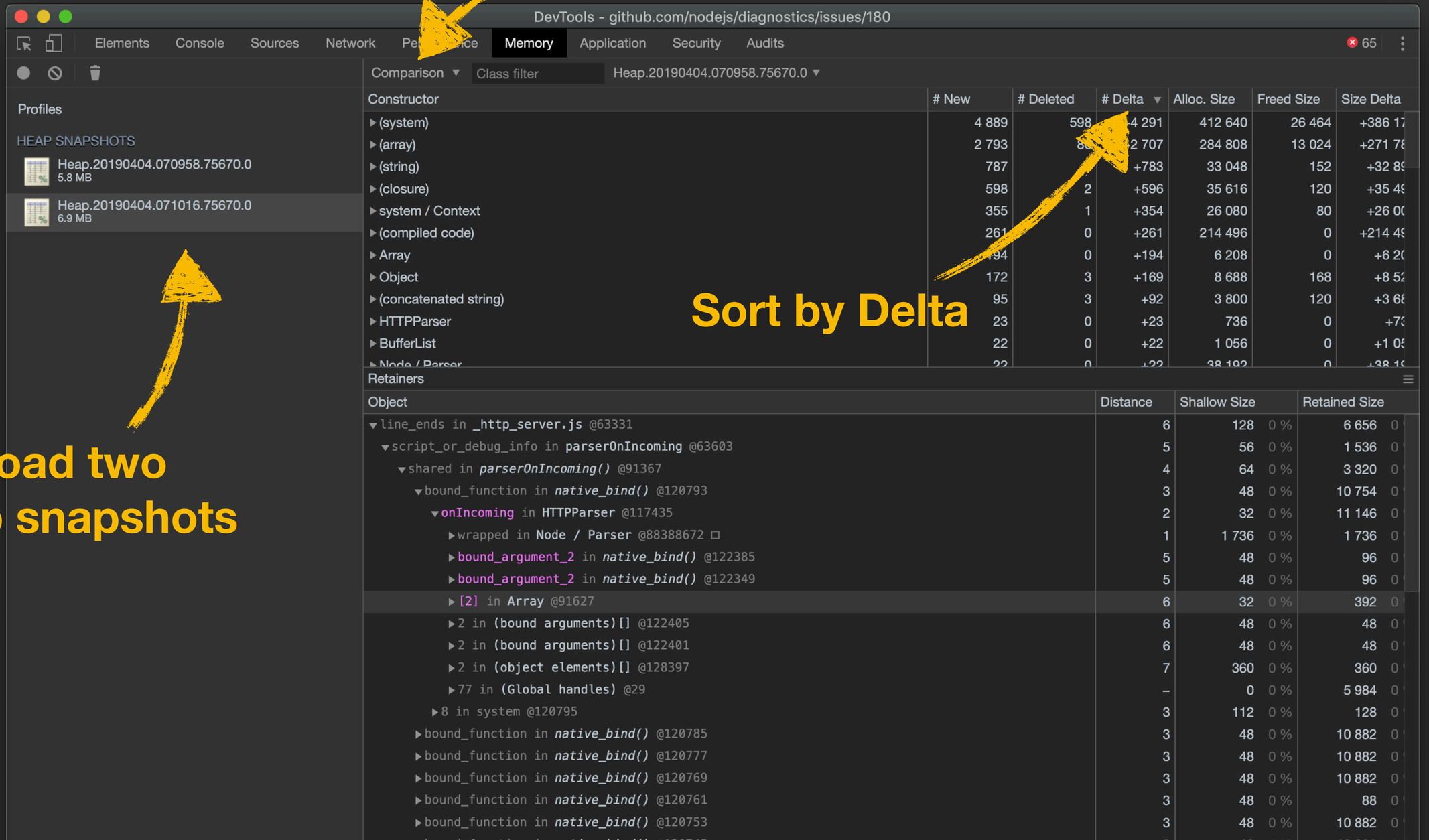
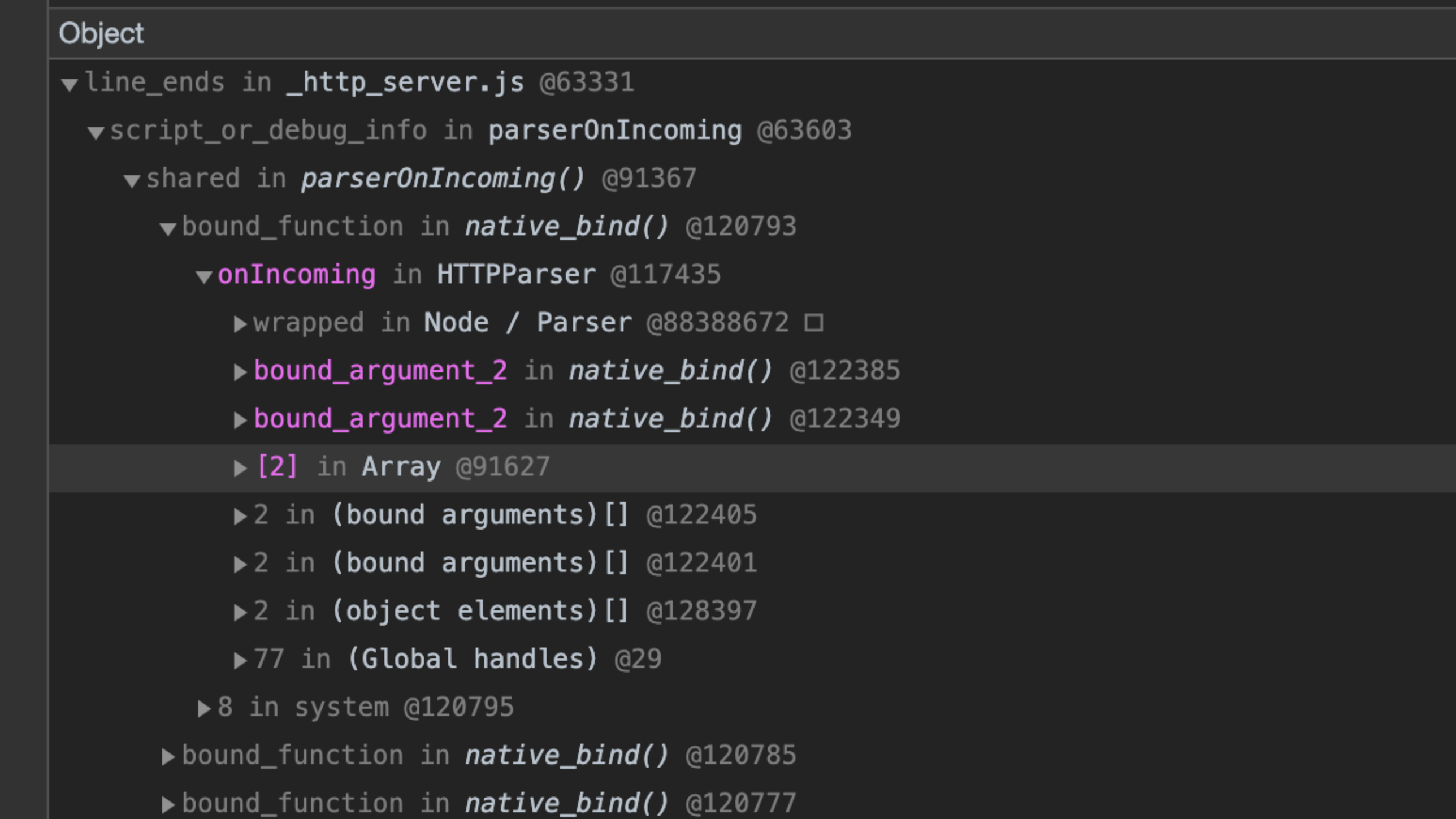
Make a diff



Sort by Delta

Load two heap snapshots


Object
line_ends in _http_server.js @63331
script_or_debug_info in parserOnIncoming @63603
shared in parserOnIncoming() @91367
bound_function in native_bind() @120793
onIncoming in HTTPParser @117435
wrapped in Node / Parser @88388672
bound_argument_2 in native_bind() @122385
bound_argument_2 in native_bind() @122349
[2] in Array @91627
2 in (bound arguments)[] @122405
2 in (bound arguments)[] @122401
2 in (object elements)[] @128397
77 in (Global handles) @29
8 in system @120795
bound_function in native_bind() @120785
bound_function in native_bind() @120777

Recap

Dev machine

- `llnode node -c core`

llnode

- `v8 help` *Get help*
- `v8 findjsobjects -d` *List all objects sorted by count*
- `v8 inspect <addr>` *Inspect object at address*
- `v8 findrefs <addr>` *Find all references to object at address*


Thank you
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elastic