Are Your V8 GC Logs Speaking to You?

About Me

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Background

- We provide **performance management services** to teams both inside and outside the group
- Alibaba is one of the largest companies in China that uses Node.js in production
  - Mostly driven by frontend devs

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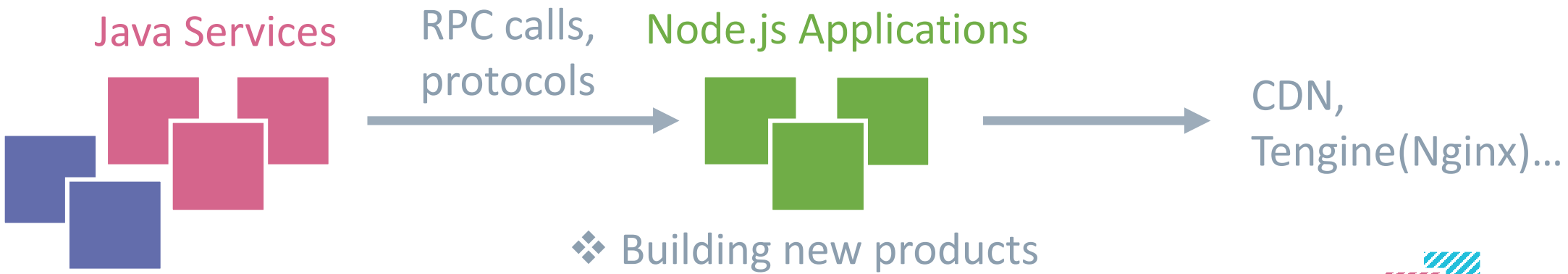
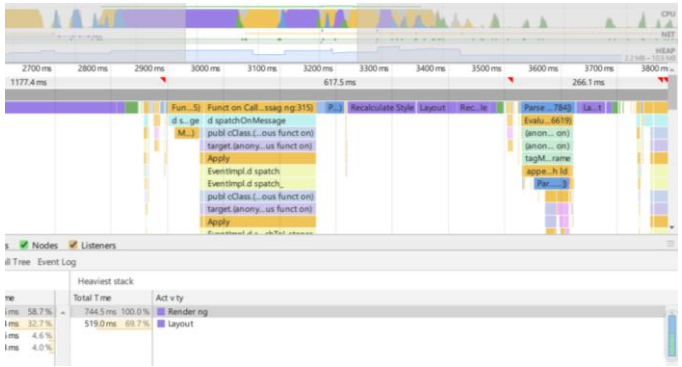


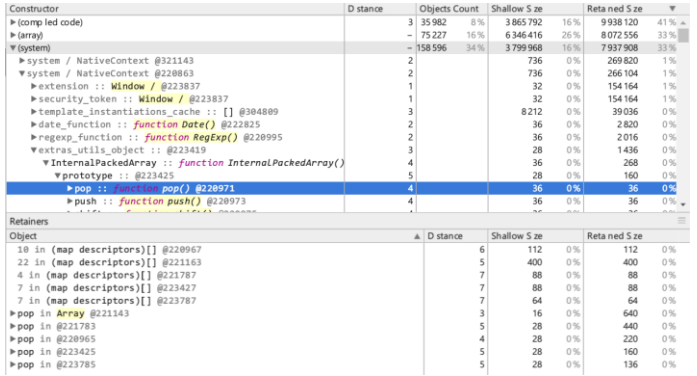
Background

- Java architects argue that Node.js is *not mature enough*
  - Lack of tooling for **monitoring and profiling**
- Java programmers *know* their VM and their GC. As for JS programmers, well…
  - Most come from a frontend dev background



CPU profile

The pursuit of 60fps



HeapSnapshopts / HeapTimelines

you don't want to blow up your users' RAM

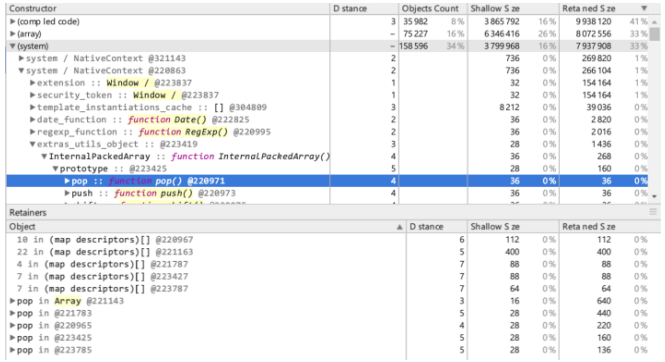
GC logs

Servers are long-running, clients are not

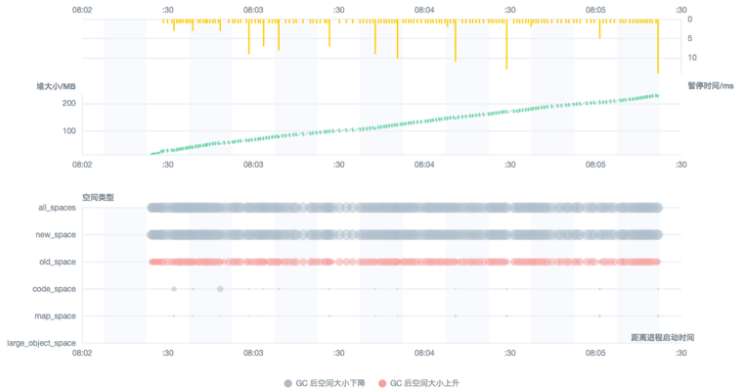
- V8 garbage collection logs are the least documented tools, not even available in devtools

What are V8 Garbage Collection logs good for?

- Combined with heap profiles, they can help you catch the culprit for memory leaks



Heapdump can tell you **what is leaking**, but they are sometimes too specific



GC logs can give you a bigger picture about what's going on, so you know **where to look**

- Help you **verify** that your fixes do fix your leaks

An introduction to V8 GC

- What is Garbage Collection(GC)?
  - Collect and free your objects(garbage) when you don't need them anymore. That's why you don't need to manage the memory yourself in languages like JavaScript, Java, Ruby…
  - For ECMAScript/JavaScript, there are no specifications about it, everything is up to the implementation
- This talk is based on V8 4.5.103.35 (the one used by Node v4.x)
  - Node v6.x will use V8 5.x, which introduces a few improvements(mostly parallel stuff) and changes the GC log format a bit, but most of this talk still apply

An introduction to V8 GC

- Generational hypothesis
  - Most objects die young, others tend to live forever
- V8 GC Strategy
  - Generational: Young and Old
  - Conservative: What's in a block memory, pointer or data? We don't know for sure! So we need to scan them.
- GC is triggered by allocations(new or var most of the time) , when the memory allocated for a space is not enough
- In V8, Objects live on the heap, and the heap is divided into spaces

An introduction to V8 GC

Code Space

Executable code compiled by V8

Map Space

Metadata of hidden classes, pointed by objects

Large Object Space

Objects too large to fit into any other spaces.

Old Space

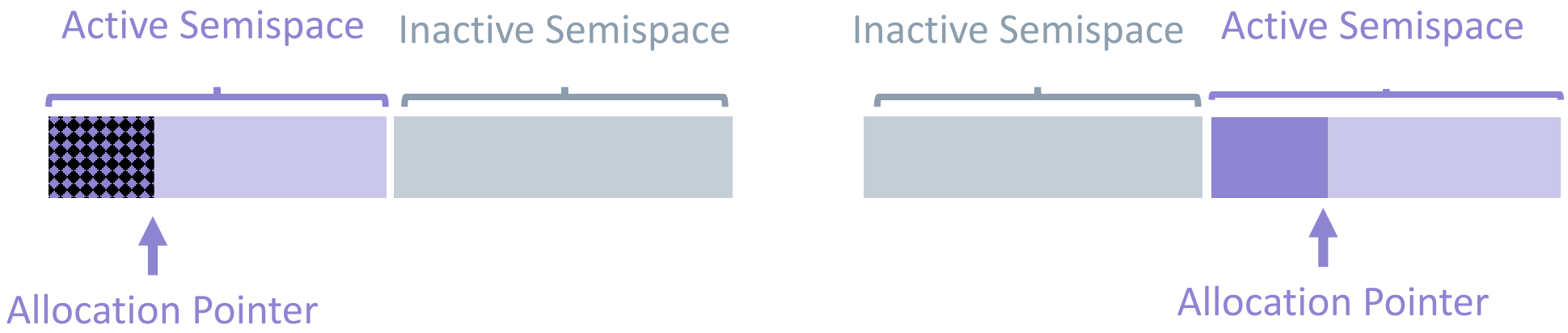
Objects survive more than two GCs in the new space

New Space

Divided in half, only one is active at a time.
Most objects start and end their lives here.

An introduction to V8 GC

- New space: Scavenger
  - Implementation of Cheney's algorithm



- Old space
  - Mark-sweep/mark-compact
- *Oddly* similar to the early HotSpot JVM(designed by the same person)
- Further reading
  - http://alinode.aliyun.com/blog/14 (Chinese)
  - http://jayconrod.com/posts/55/a-tour-of-v8-garbage-collection (English)

Getting started with V8 GC logs

- Plenty of options(`node --v8-options| grep gc`)
- We'll be focusing on
  - `--trace_gc`
  - `--trace_gc_nvp`
- Obviously you can't use these in production, even though it would be difficult to reproduce your problems offline
  - `v8.setFlagsFromString('--trace_gc')`
  - `v8.setFlagsFromString('--notrace_gc')`
  - Or use alinode to get them by clicking a button on our SAAS platform(wink wink)
- In case you do want to read the code
  - `deps/v8/src/heap`, start with `gc-tracer.cc`

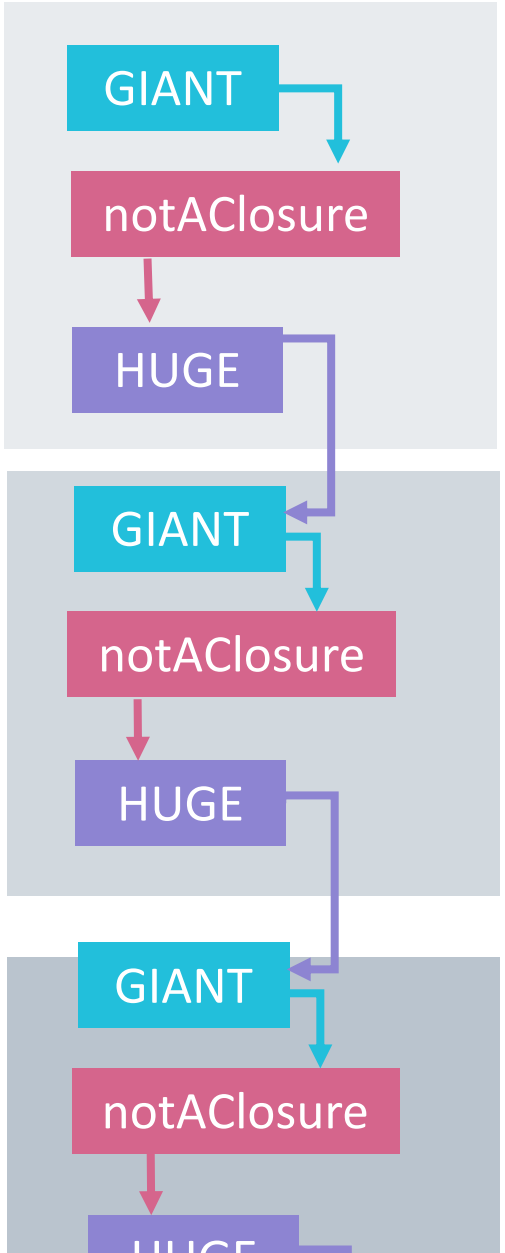
Demo Time

Leaks caused by closures

- Closures are created when declared, not when executed
- In V8, once there is any closure in the context, the context will be attached to every function, even for those who don't reference the context at all

```
const express = require('express');
const app = express();

var GIANT;

function leak() {
  var HUGE = GIANT;

  function unusedClosure() {
    HUGE.slice(1);
  }

  GIANT = {
    willBeLeaked: new Array(1e5).join('.'),
    notAClosure: function notAClosure() {
      return 1;
    }
  }
}

app.get('/', function handler(req, res) {
  leak();
  console.log(new Date());
  res.send('Hello World!');
});

app.listen(3000, function startApp() {
  console.log('Example app listening on port 3000!');
});
```

Leaks caused by closures



Created in this call

Created in last call, but can't be GC'ed because they are referenced by the new ones

```
const express = require('express');
const app = express();

var GIANT;

function leak() {
  var HUGE = GIANT;

  function unusedClosure() {
    HUGE.slice(1);
  }

  GIANT = {
    willBeLeaked: new Array(1e5).join('.'),
    notAClosure: function notAClosure() {
      return 1;
    }
  }
}

app.get('/', function handler(req, res) {
  leak();
  console.log(new Date());
  res.send('Hello World!');
});

app.listen(3000, function startApp() {
  console.log('Example app listening on port 3000!');
});
```

This shouldn't have happened!

It happens because of this

Leaks caused by closures

Constructor	Distance	Objects C...	Shallow Size	Retained Size ▼
▼(string)	3	723 27%	031 696 98%	031 696 98%
".....	6172		100 024 0%	100 024 0%
".....	6175		100 024 0%	100 024 0%
".....	3988		100 024 0%	100 024 0%
".....	4372		100 024 0%	100 024 0%
".....	4375		100 024 0%	100 024 0%
".....	3985		100 024 0%	100 024 0%
".....	3619		100 024 0%	100 024 0%
".....	3622		100 024 0%	100 024 0%
".....	2806		100 024 0%	100 024 0%
".....	2809		100 024 0%	100 024 0%

Retainers

Object	Distance ▲	Shallow Size	Retained Size
▼willBeLeaked in @13957	6171	40 0%	40 0%
▼HUGE in system / Context @100513	6170	56 0%	56 0%
▼context in function() @100511	6169	72 0%	72 0%
▼notAClosure in @100507	6168	40 0%	40 0%
▼HUGE in system / Context @100505	6167	56 0%	56 0%
▼context in function() @100503	6166	72 0%	72 0%
▼notAClosure in @100499	6165	40 0%	40 0%
▼HUGE in system / Context @100497	6164	56 0%	56 0%
▼context in function() @100495	6163	72 0%	72 0%
▼notAClosure in @100491	6162	40 0%	40 0%
▼HUGE in system / Context @100489	6161	56 0%	56 0%
▼context in function() @100487	6160	72 0%	72 0%
▼notAClosure in @100483	6159	40 0%	40 0%
▼HUGE in system / Context @100481	6158	56 0%	56 0%
▼context in function() @100479	6157	72 0%	72 0%
▼notAClosure in @100475	6156	40 0%	40 0%

Leaks caused by closures

- --trace_gc (print one trace line following each garbage collection)

PID:Address

The time since you start this VM

Size of memory allocated from OS

Spent on external memory

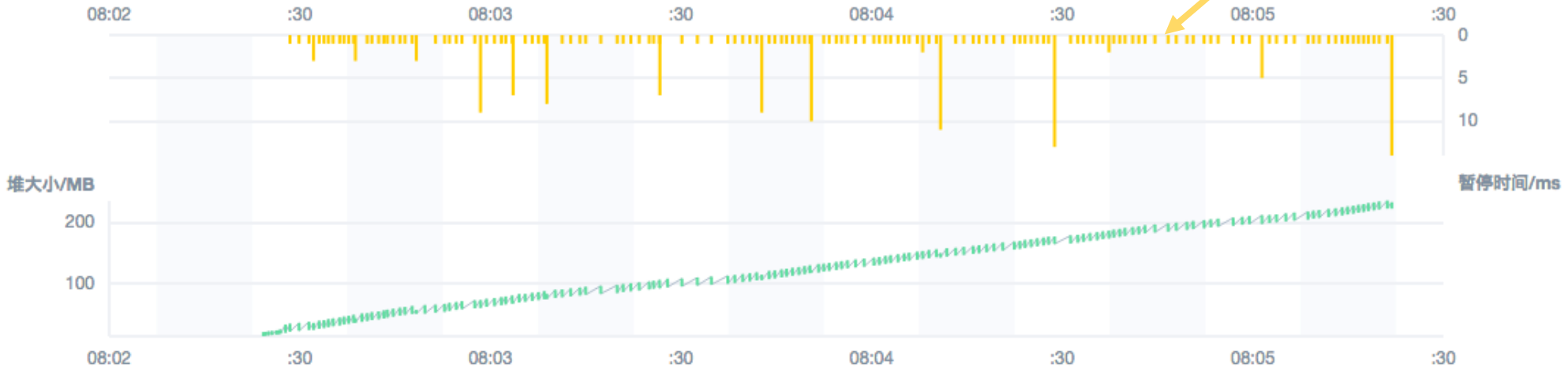
```
[19642:0x102004a00]   611604 ms: Scavenge 1153.6 (1457.9) -> 1152.9 (1457.9) MB, 0.6 / 0 ms [allocation failure].
[19642:0x102004a00]   611774 ms: Scavenge 1153.7 (1457.9) -> 1152.9 (1457.9) MB, 0.6 / 0 ms [allocation failure].
[19642:0x102004a00]   611775 ms: Scavenge 1153.7 (1457.9) -> 1153.0 (1457.9) MB, 0.6 / 0 ms [allocation failure].
[19642:0x102004a00]   611880 ms: Scavenge 1153.1 (1457.9) -> 1153.1 (1457.9) MB, 0.5 / 0 ms [allocation failure].
[19642:0x102004a00]   611881 ms: Scavenge 1153.1 (1457.9) -> 1153.1 (1457.9) MB, 0.5 / 0 ms [allocation failure].
[19642:0x102004a00]   611916 ms: Mark-sweep 1153.1 (1457.9) -> 1152.4 (1449.9) MB, 35.0 / 0 ms [last resort gc].
[19642:0x102004a00]   611951 ms: Mark-sweep 1152.4 (1449.9) -> 1152.3 (1442.9) MB, 34.8 / 0 ms [last resort gc].
```

Type of GC

Size of all objects

Pause

Because the GC is triggered when there's not enough memory



Leaks caused by closures

- --trace_gc_nvp (print one detailed trace line in name=value format after each garbage collection)

Name-value

Type of GC, ms=Mark-sweep/Mark-compact, s=Scavenger

```
[12543:0x102004a00] [I:0x102004a00]   152163 ms: pause=3.2 mutator=729.4 gc=ms external=0.0 mark=0.3 sweep=2.27
sweepns=1.53 sweepos=0.15 sweepcode=0.18 sweepcell=0.00 sweepmap=0.05 evacuate=0.0 new_new=0.0 root_new=0.0
old_new=0.0 compaction_ptrs=0.0 intracompaction_ptrs=0.0 misc_compaction=0.3 weak_closure=0.0 inc_weak_closure=0.0
weakcollection_process=0.0 weakcollection_clear=0.0 weakcollection_abort=0.0 total_size_before=37492960
total_size_after=25744424 holes_size_before=2600536 holes_size_after=3375144 allocated=11756832 promoted=1407928
semi_space_copied=1119104 nodes_died_in_new=12 nodes_copied_in_new=1 nodes_promoted=0 promotion_ratio=10.6%
average_survival_ratio=17.5% promotion_rate=97.4% semi_space_copy_rate=8.4% new_space_allocation_throughput=14433
context_disposal_rate=0.0 steps_count=51 steps_took=7.2 longest_step=0.9 incremental_marking_throughput=2560955
[12543:0x102004a00] Memory allocator, used: 65476 KB, available: 1433660 KB
[12543:0x102004a00] New space,      used:   1105 KB, available:  15018 KB, committed:  32248 KB
[12543:0x102004a00] Old space,      used:  22174 KB, available:   2622 KB, committed:  25049 KB
[12543:0x102004a00] Code space,     used:   1617 KB, available:    622 KB, committed:   2266 KB
[12543:0x102004a00] Map space,      used:    243 KB, available:    810 KB, committed:   1070 KB
[12543:0x102004a00] Large object space, used:      0 KB, available: 1432619 KB, committed:      0 KB
[12543:0x102004a00] All spaces,         used:  25141 KB, available: 1451694 KB, committed:  60634 KB
[12543:0x102004a00] External memory reported:     16 KB
[12543:0x102004a00] Total time spent in GC  : 32.5 ms
```

Allocatable memory and page headers

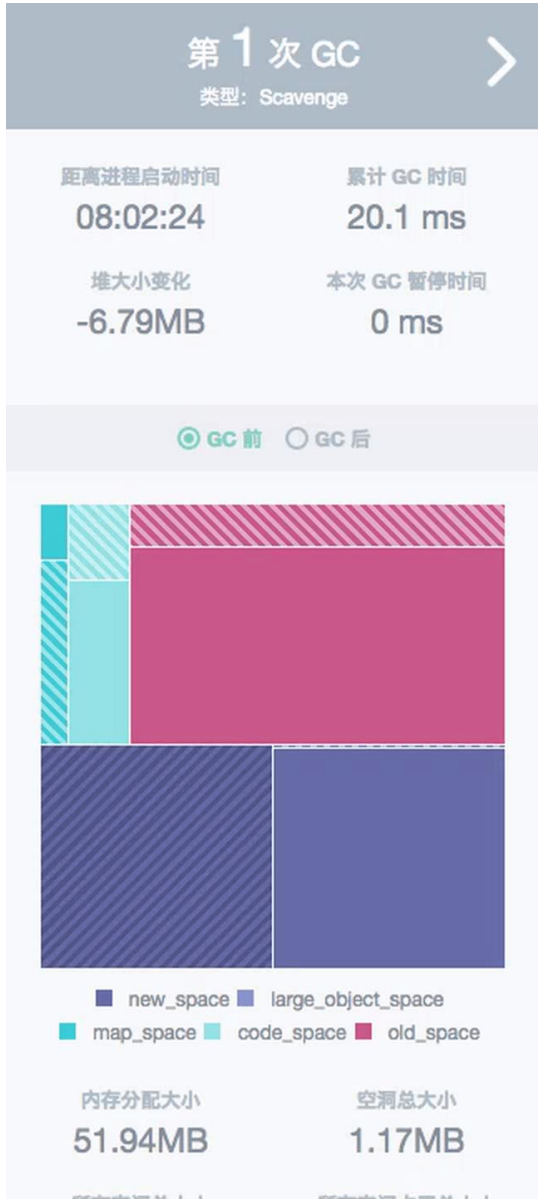
Memory left in the allocator

committed = (available + used)(*2 if it's new space)

Statistics of each space

Leaks caused by closures

Leaks caused by closures



Leaks caused by closures

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

- deps/v8/src/api.cc: ResourceConstraints::ConfigureDefaults

```
const uint64_t low_limit = 512ul * i::MB;
const uint64_t medium_limit = 768ul * i::MB;
const uint64_t high_limit = 1ul  * i::GB;
```

- deps/v8/src/heap/heap.h

```
// The old space size has to be a multiple of Page::kPageSize.
// Sizes are in MB.
static const int kMaxOldSpaceSizeLowMemoryDevice = 128 * kPointerMultiplier;
static const int kMaxOldSpaceSizeMediumMemoryDevice =
    256 * kPointerMultiplier;
static const int kMaxOldSpaceSizeHighMemoryDevice = 512 * kPointerMultiplier;
static const int kMaxOldSpaceSizeHugeMemoryDevice = 700 * kPointerMultiplier;
```

```
static const int kPointerMultiplier = i::kPointerSize / 4;
```

```
const int kPointerSize   = sizeof(void*);     // NOLINT
```

Leaks caused by closures

Solution #1: nullify your reference

- Cut off the reference to the old GIANT when you don't need it anymore

```
var GIANT;

function leak() {
  var HUGE = GIANT;

  function unusedClosure() {
    HUGE.slice(1);
  }

  GIANT = {
    willBeLeaked: new Array(1e5).join('.'),
    notAClosure: function notAClosure() {
      return 1;
    }
  }

  HUGE = null;  /* not used anymore! */
}
```

Solution #1: nullify your reference

Solution #2: passing parameters

- Avoid closure like a plague

```
var GIANT;

function leak() {
  var HUGE = GIANT;

  function notAClosureAnymore(HUGE_ARG) {
    HUGE_ARG.slice(1);
  }

  GIANT = {
    willBeLeaked: new Array(1e5).join('.'),
    notAClosure: function notAClosure() {
      return 1;
    }
  }
}
```

Solution #2: passing parameters

Questions?

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