Artifact * AEC * Evaluated * PLDI *
Consistent * Complete * Well Documented * Easy to Reuse *

Idle Time Garbage Collection Scheduling

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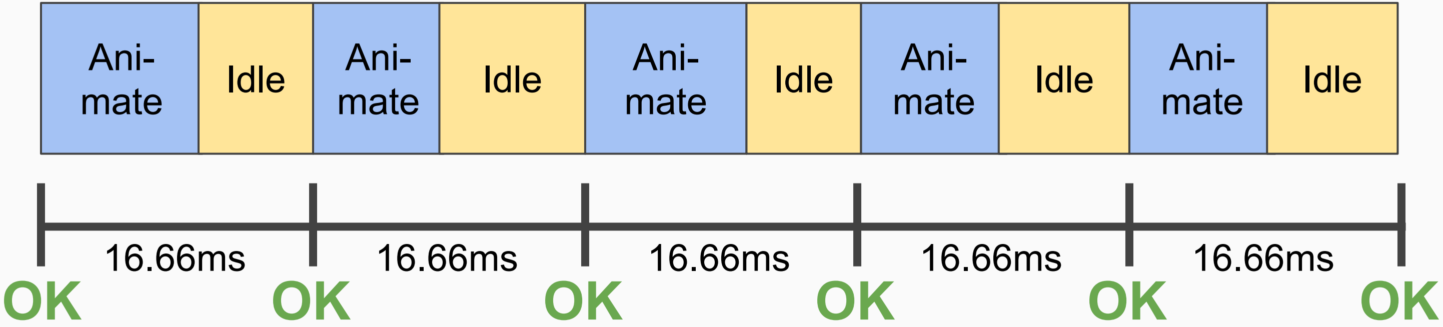
Google

Overview

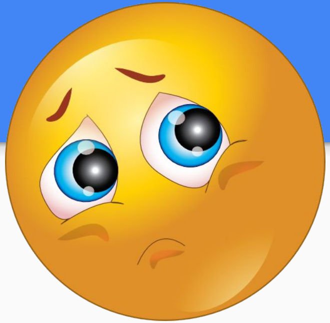
- Chrome & V8
- Idle Time Garbage Collection Scheduling for
  - Improving Latency
  - Improving Memory Consumption
- Experiments
- Related Work
- Conclusions

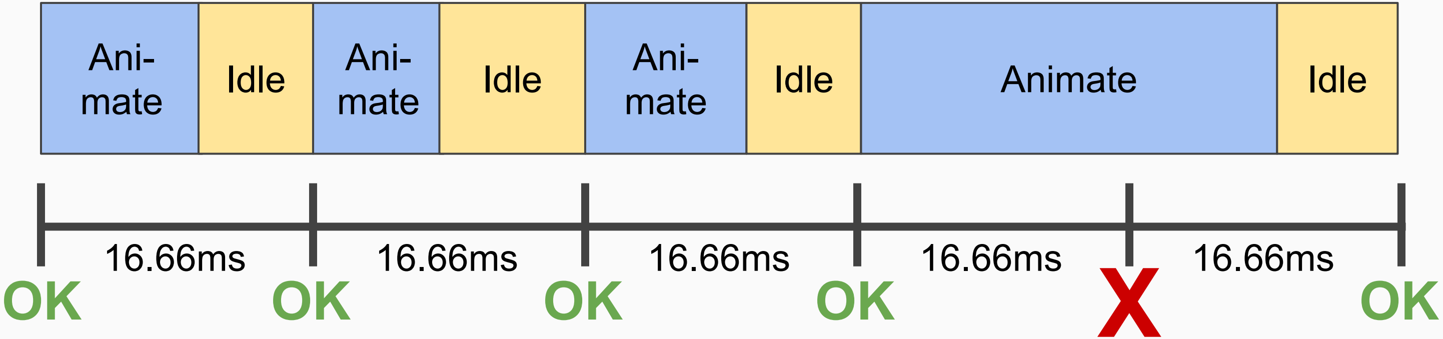
+ 60 fps = 😍

Animating at 60 fps



Dropping Frames

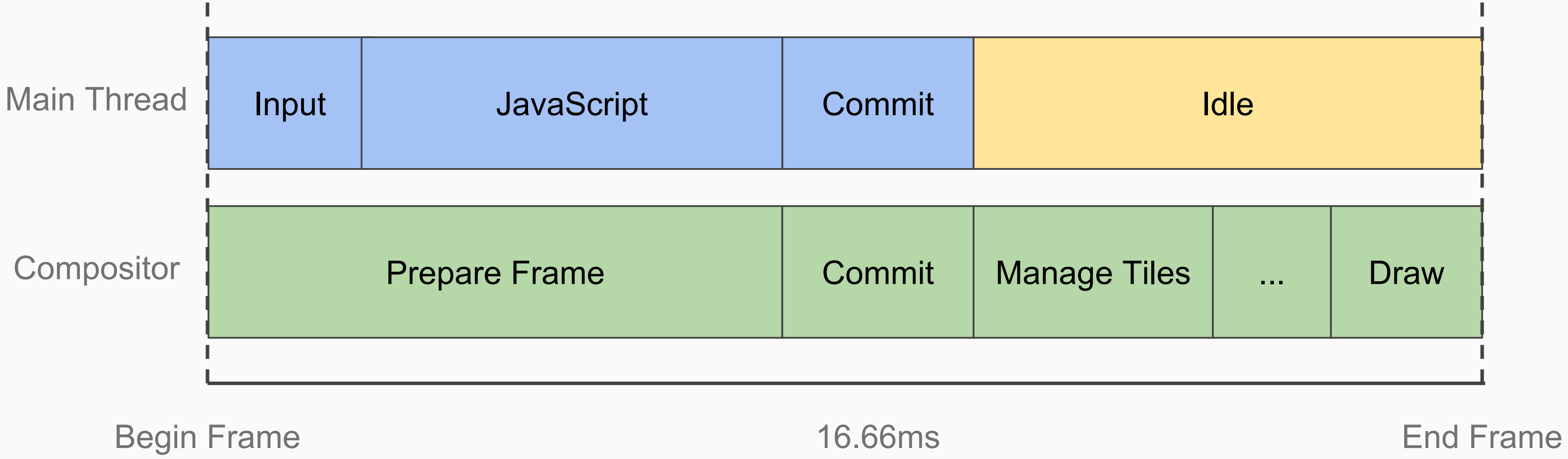




Five Fun Facts About Chrome & V8

- JavaScript is single threaded and runs on the *main thread*
- V8 is the JavaScript virtual machine used within Chrome
- DOM can be modified using JavaScript to perform animation
- The compositor is responsible for drawing DOM changes
- Task scheduler schedules tasks on main thread
  - Provides idle tasks

Chrome & V8


Main Thread
Input
JavaScript
Commit
Idle
Compositor
Prepare Frame
Commit
Manage Tiles
...
Draw
Begin Frame
16.66ms
End Frame

V8 Garbage Collection

- Weak generational hypothesis: “Most objects die young”
- V8 implements a generational garbage collector
  - Young generation (up to 16M)
  - Old generation (up to 1.4G)
- Dynamic allocation site based pretenuring

  Daniel Clifford, Hannes Payer, Michael Stanton, and Ben L. Titzer. 2015. Memento mori: dynamic allocation-site-based optimizations. In Proceedings of the 2015 International Symposium on Memory Management (ISMM '15). ACM, New York, NY, USA, 105-117.

Young Generation Garbage Collection

Cheney-style semi-space scavenger

- Triggers when a semi-spaces becomes full
- Copies live objects to the other semi-space or promotes objects
- Runtime is linear in number of live objects
- Can not be interrupted

Full Garbage Collection

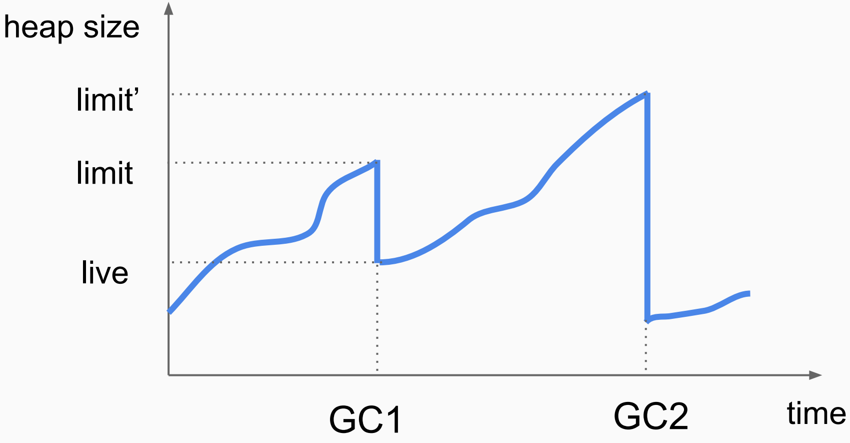
Mark-sweep collector with compaction

- Mark young and old generation
- Incremental marking
- Concurrent sweeping
- Young generation evacuation
- Compaction

Full Garbage Collection

Mark-sweep collector with compaction

- Incremental marking starts close to heap limit determined by heap growing strategy
- limit’ = live object size x [1.1, 4]

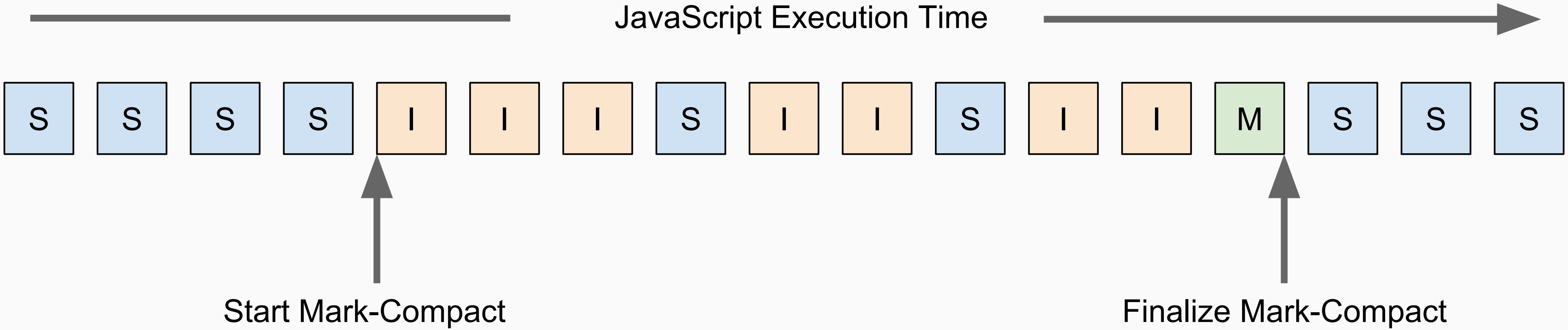


V8 Garbage Collection

S Scavenger (~0-10 ms)

I Incremental Marking (~0.01-CONFIGURABLE ms)

M Finalization Mark-Compact Collection (~4-20 ms)



JavaScript Execution Time

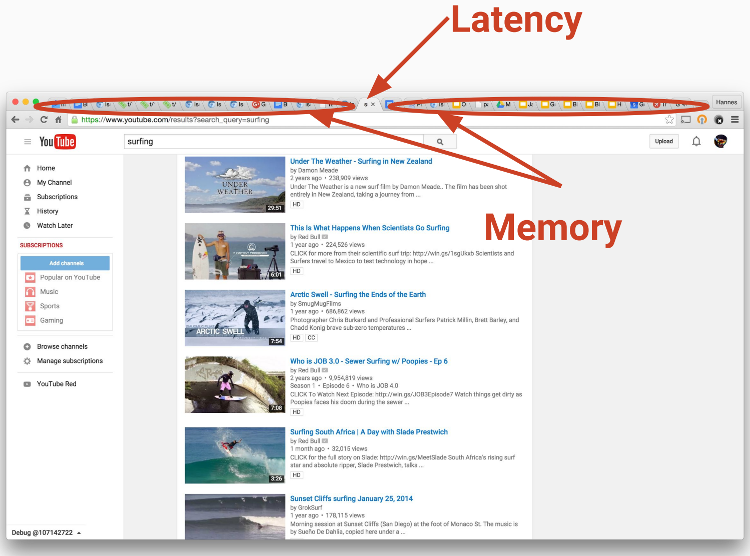
S S S S I I I S I I S I I M S S S

Start Mark-Compact

Finalize Mark-Compact

Chrome, a funky place for garbage collection

- Foreground tab
  - Latency matters
  - New frames are drawn every 16.66 ms when animation or scrolling happens
  - Reducing memory becomes important as soon as the tab becomes inactive
- Background tab
  - Reduce memory consumption
  - Latency is secondary



Latency

Memory

https://www.youtube.com/results?search_query=surfing

surfing

Under The Weather - Surfing in New Zealand
by Damon Meade
2 years ago • 238,909 views
Under The Weather is a new surf film by Damon Meade.. The film has been shot entirely in New Zealand, taking a journey from ...
HD

This Is What Happens When Scientists Go Surfing
by Red Bull
1 year ago • 224,526 views
CLICK for more from their scientific surf trip: http://win.gs/1sgUkxb Scientists and Surfers travel to Mexico to test technology in hope ...
HD

Arctic Swell - Surfing the Ends of the Earth
by SmugMugFilms
1 year ago • 686,862 views
Photographer Chris Burkard and Professional Surfers Patrick Millin, Brett Barley, and Chadd Konig brave sub-zero temperatures ...
HD CC

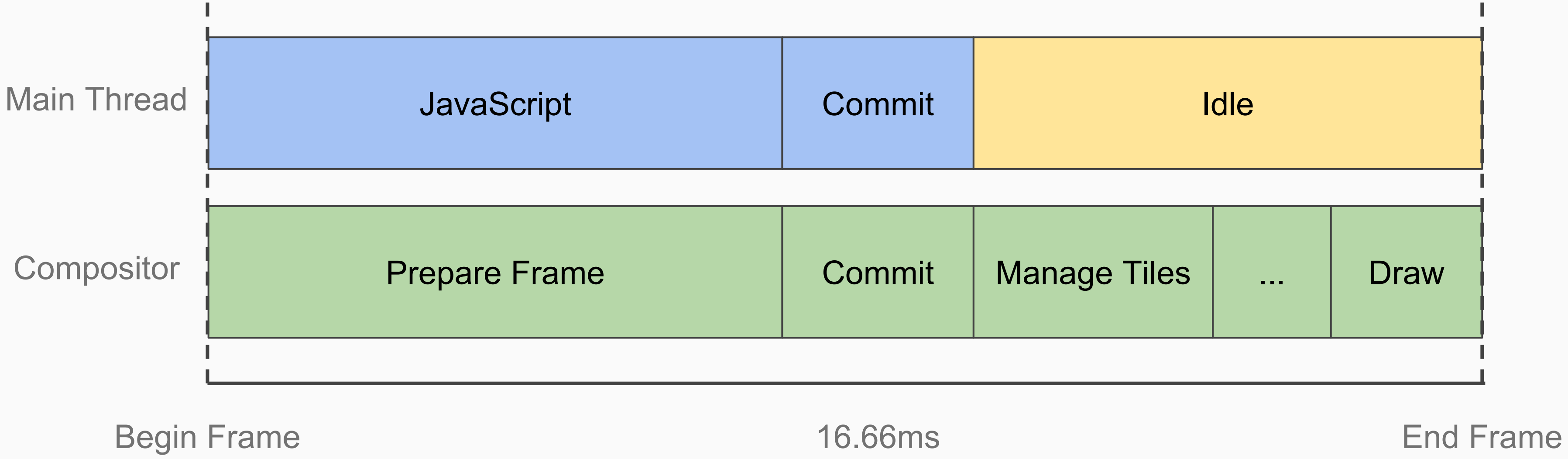
Who is JOB 3.0 - Sewer Surfing w/ Poopies - Ep 6
by Red Bull
2 years ago • 9,954,819 views
Season 1 • Episode 6 • Who is JOB 4.0
CLICK To Watch Next Episode: http://win.gs/JOB3Episode7 Watch things get dirty as Poopies faces his doom during the sewer ...
HD

Surfing South Africa | A Day with Slade Prestwich
by Red Bull
1 month ago • 32,015 views
CLICK for the full story on Slade: http://win.gs/MeetSlade South Africa's rising surf star and absolute ripper, Slade Prestwich, talks ...
HD

Sunset Cliffs surfing January 25, 2014
by GrokSurf
1 year ago • 178,115 views
Morning session at Sunset Cliffs (San Diego) at the foot of Monaco St. The music is by Sueño De Dahlia, copied here under a ...

Latency

Life of a Frame



Main Thread

JavaScript

Commit

Idle

Compositor

Prepare Frame

Commit

Manage Tiles

...

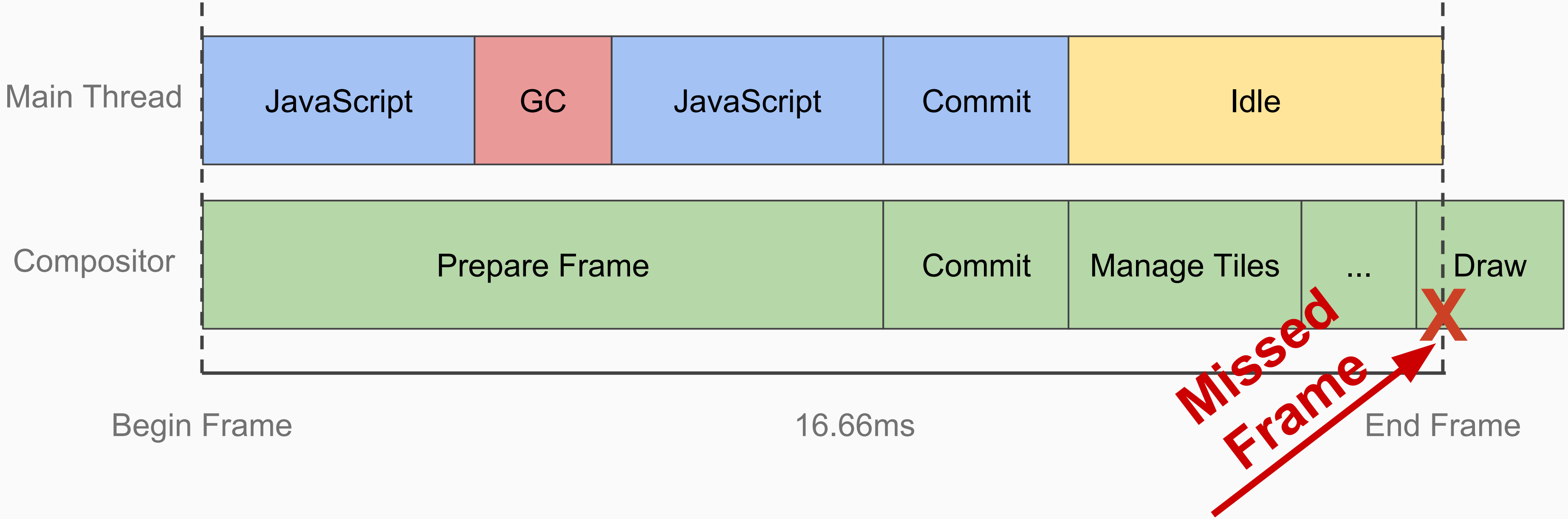
Draw

Begin Frame

16.66ms

End Frame

Life of a Frame



Main Thread

JavaScript

GC

JavaScript

Commit

Idle

Compositor

Prepare Frame

Commit

Manage Tiles

...

Draw

X

Missed Frame

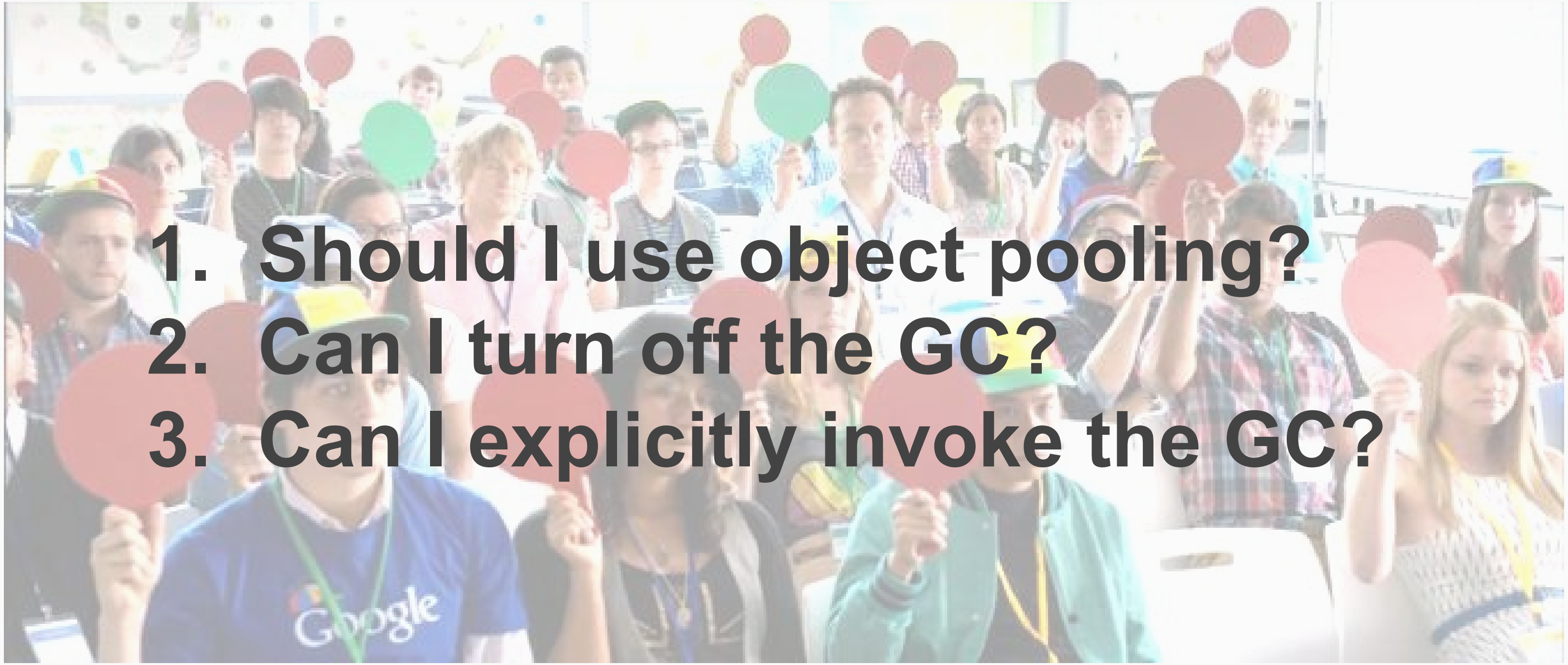
Begin Frame

16.66ms

End Frame

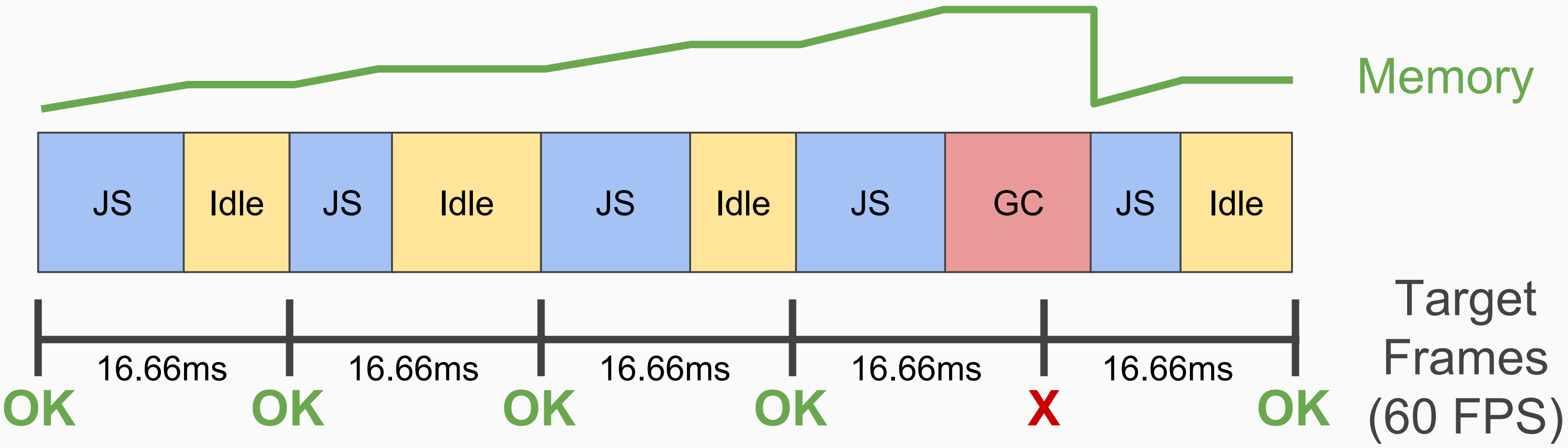
The Three Deadly Sins of Garbage Collection

The Three Deadly Sins of Garbage Collection

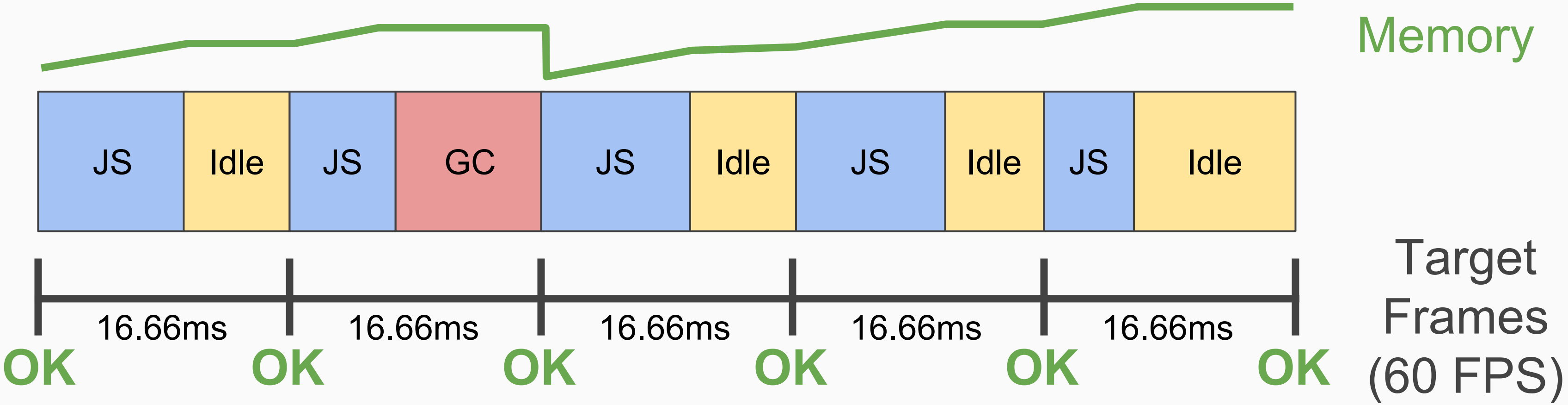


1. **Should I use object pooling?**
2. **Can I turn off the GC?**
3. **Can I explicitly invoke the GC?**

Life of a Frame



Life of a Frame



Idle Time Garbage Collection Scheduling

Step 1

Registering GC Idle Task

- V8 GC checks every *n* allocations or *m* time units if a garbage collection event may happen soon.
- V8 GC registers an idle task for the event in the task scheduler.

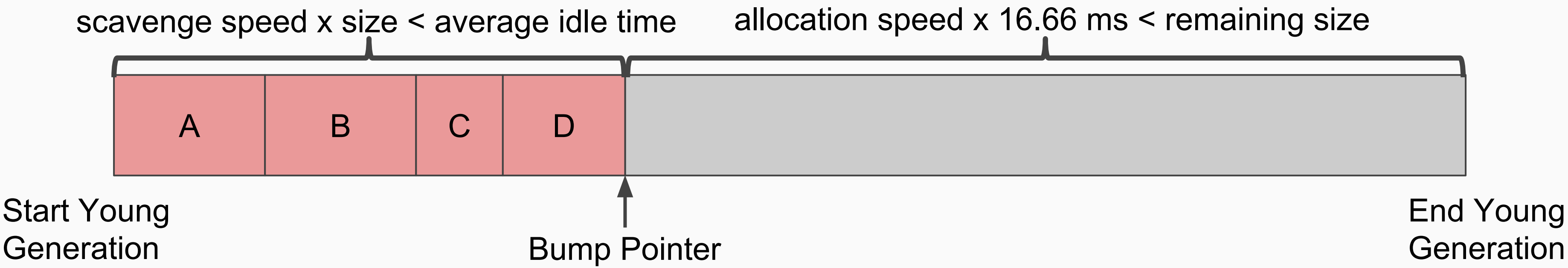
Idle Time Garbage Collection Scheduling

Step 2

Handling GC Idle Task

- The task scheduler will schedule the idle task and invoke the given callback with the available idle time.
- V8 GC will check if the task is still pending and if enough idle time is provided to handle the task.

Scheduling Young Generation GCs


scavenge speed x size < average idle time
allocation speed x 16.66 ms < remaining size
A
B
C
D
Start Young Generation
Bump Pointer
End Young Generation

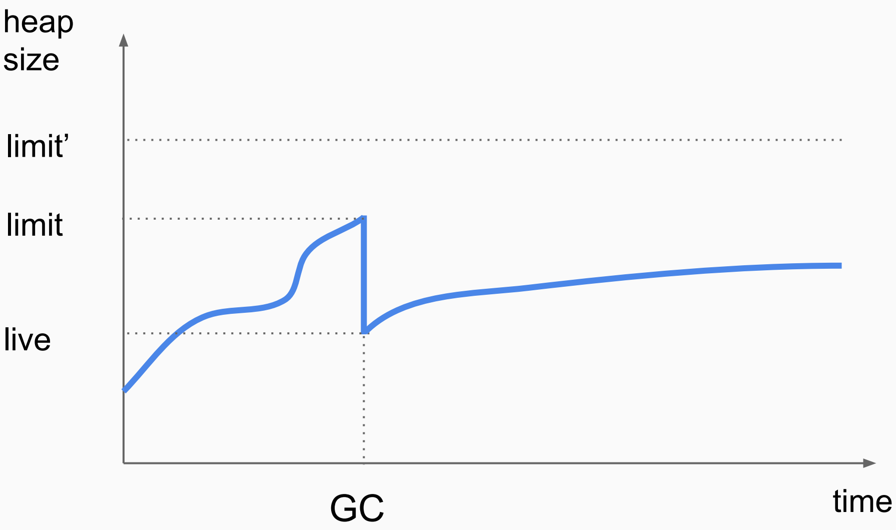
- Allocation interrupt at every 512K of allocations
  - Check if GC will happen within this frame or if there is more time based on average allocation rate and current heap size?
  - Compute how much idle time we have on average and how long young generation garbage collections take on average to proactively schedule garbage collections.

Scheduling Full GCs

- Incremental marking is started close to the old generation limit
- Incremental marking steps
  - Average marking speed in bytes/sec
  - Current idle task deadline
- Finalization of full garbage collection
  - Performed when marking is almost done
  - Average full garbage collection finalization time
  - Current idle task deadline

Memory

Memory Reducing GCs for Inactive Tabs



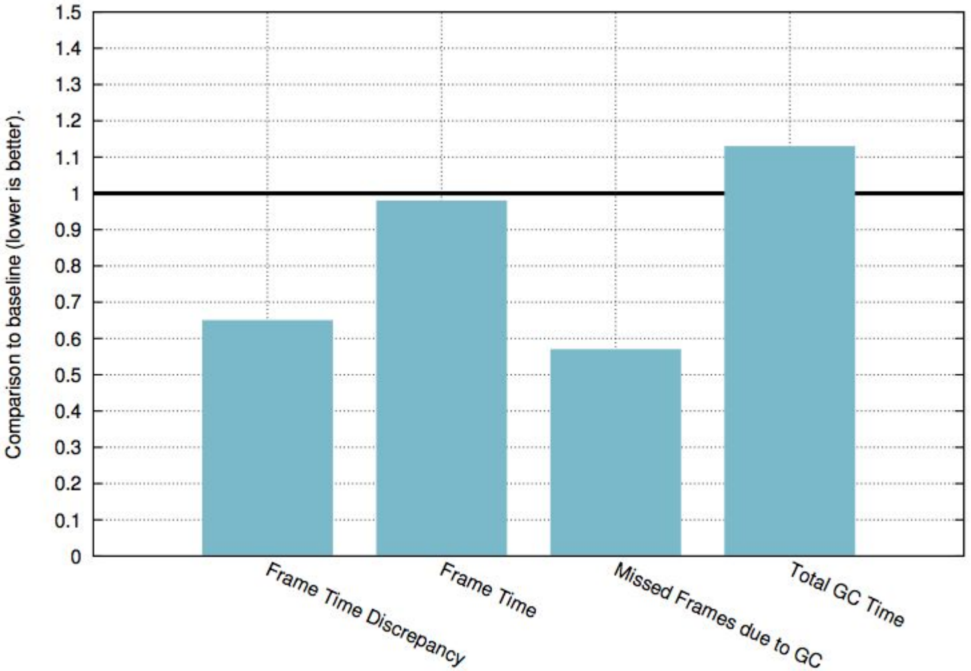
- Started only when JavaScript allocation rate and the rate of JavaScript invocations become low
- Watchdog checks state every 8 seconds
- Register memory reducing idle task
- Idle time up to 50ms is provided by the scheduler

Experiments

Experiments

- Chrome version 48.0.2564.109 (February 2016)
- Platforms
  - Linux workstation with two Intel Xeon E5-2680 V2 deca-core 2.80 GHz CPUs and 64GB of main memory
  - Nexus 6P Android smartphone with 3GB of main memory and a BIG.little configuration of a Quad-core 1.55 GHz Cortex A53 and a Quad-core 2.0 GHz Cortex-A57.
- Chrome’s Telemetry performance benchmarking framework to evaluate recorded samples of real webpages
- Baseline Chrome with *--disable-v8-idle-tasks*
- Each benchmark run was repeated 20 times

oortonline.gl



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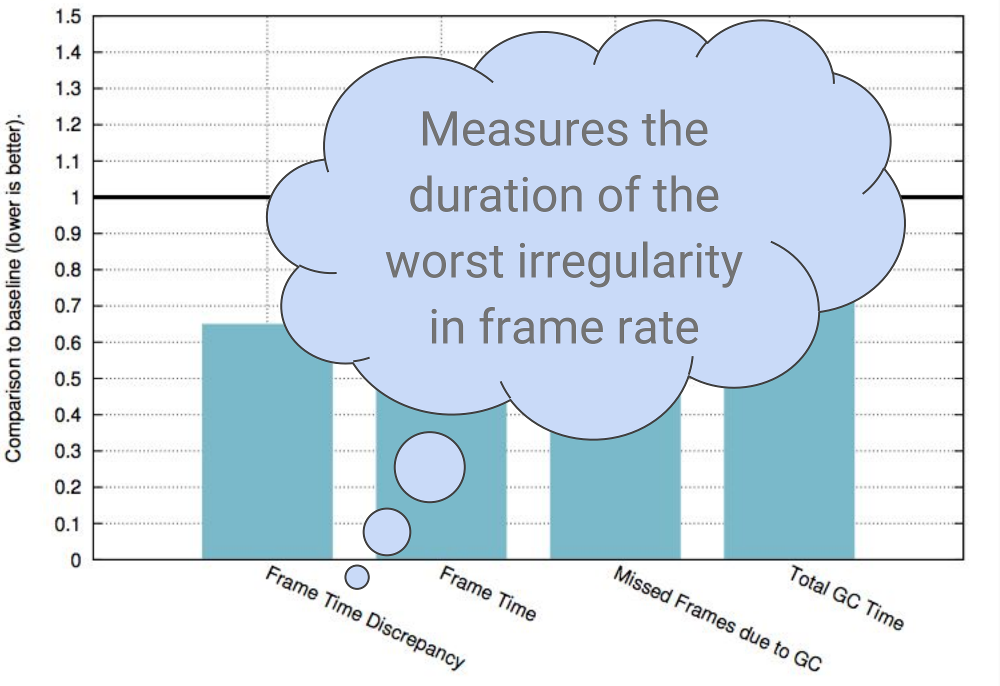
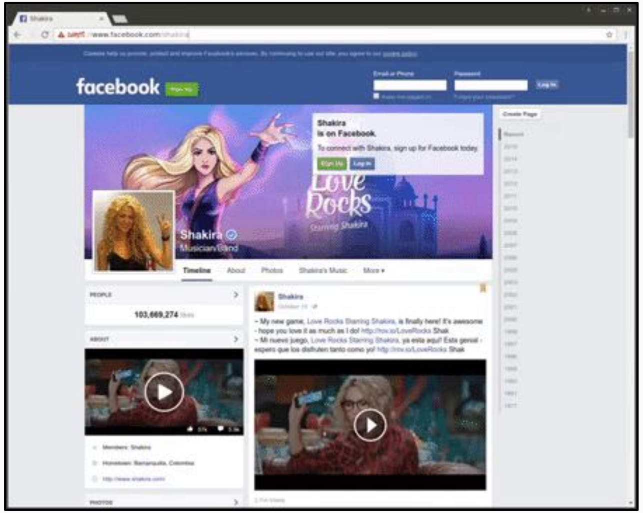


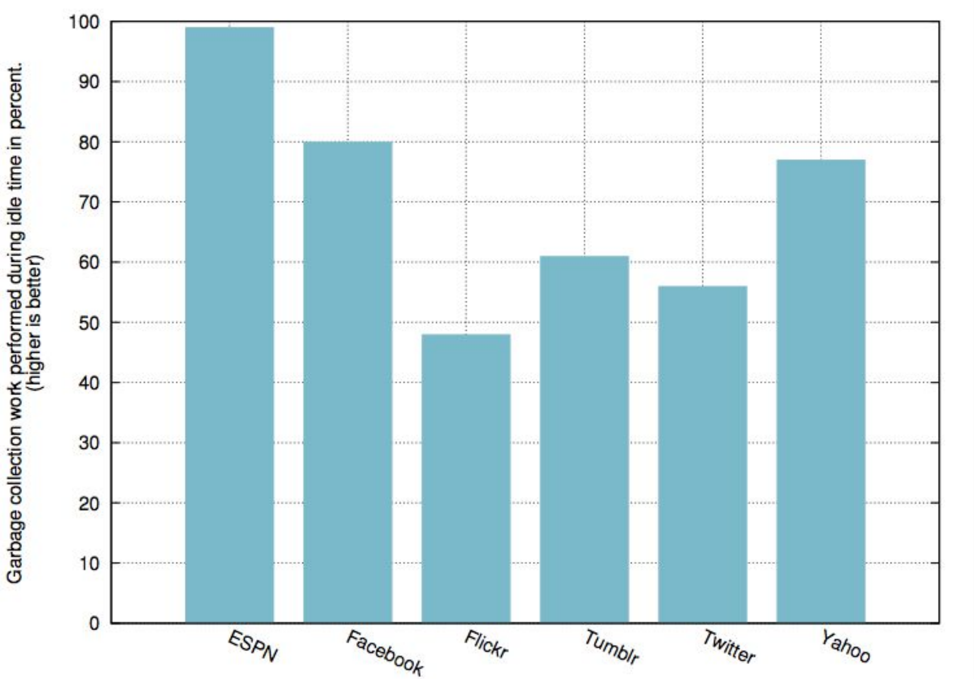
Measures the duration of the worst irregularity in frame rate

Infinite Scrolling Webpages

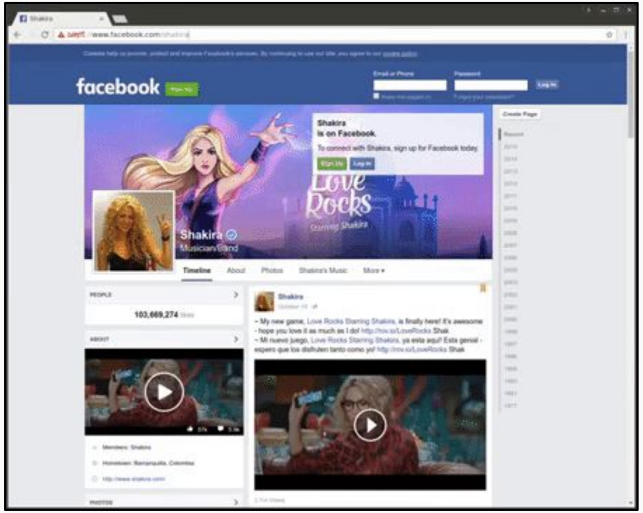


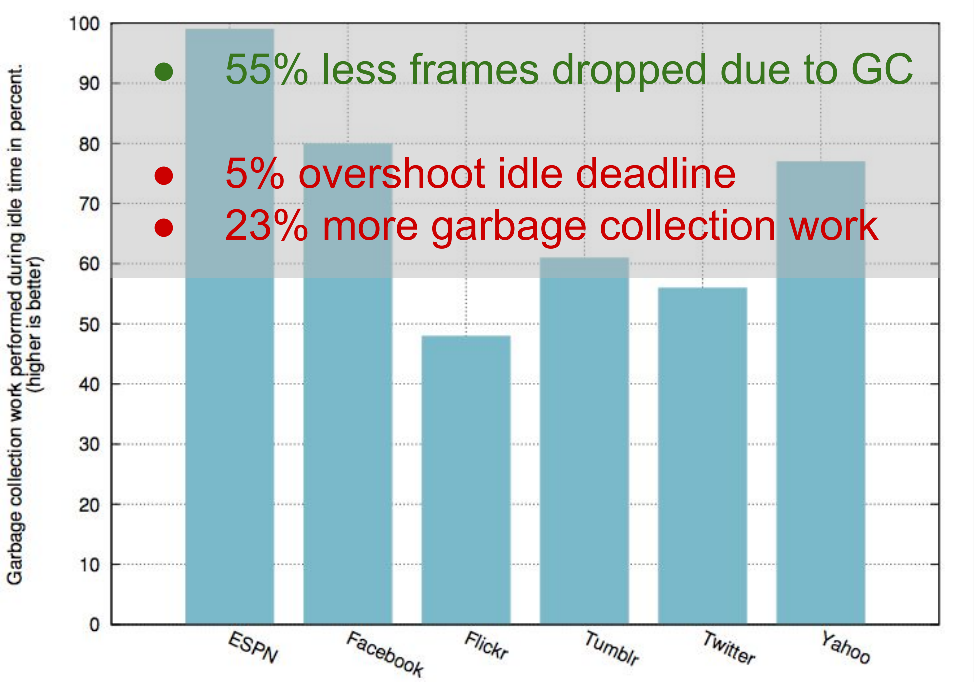
Shakira

- My new game, Love Rocks Starring Shakira, is finally here! It's awesome - hope you love it as much as I do! http://rov.io/LoveRocks Shak
- Mi nuevo juego, Love Rocks Starring Shakira, ya esta aqui! Esta genial - espero que los disfruten tanto como yo! http://rov.io/LoveRocks Shak



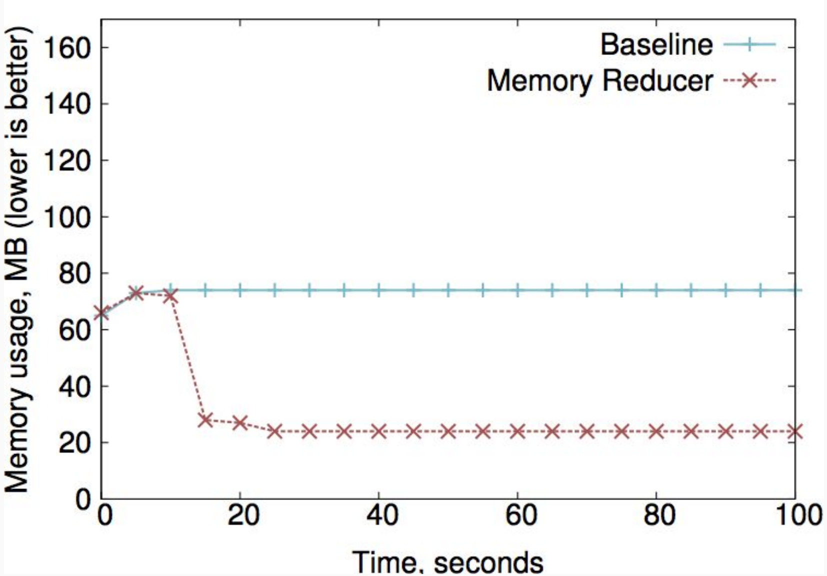
Infinite Scrolling Webpages



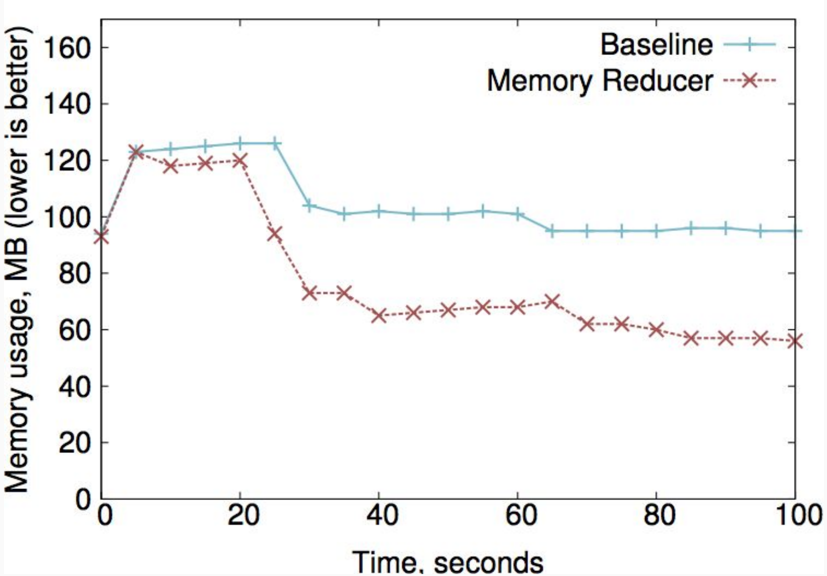


- 55% less frames dropped due to GC
- 5% overshoot idle deadline
- 23% more garbage collection work

Memory Reducer: Idle Webpages



Google Search



Google Docs

Related Work

- Idle time garbage collection
    - Periodic: Metronome Bacon et. al POPL’03
    - Slack-based: Henriksson et. al LCTES’03
    - Hybrid: Metronome-TS Auerbach et. al EMSOFT’08
    - Kalibera et. al TOCS’11 found that hybrid systems are superior
- Concurrent, parallel, and incremental garbage collection
    - Can be combined with idle time garbage collection scheduling
    - Costly memory compaction phases can be hidden during idle time without introducing memory or barrier overhead

Conclusions

- Idle time garbage collection scheduling may
  - improve responsiveness and
  - decrease memory consumption of webpages
  - without introducing additional garbage collection implementation complexity.
- Shipped and enabled in Chrome by default
- New metric *frame time discrepancy* to better quantify user experience
- Applicability:
  - Other virtual machines that are aware of screen rendering
  - Servers that are not constantly under 100% CPU load, e.g. node.js

Thank you!
Questions?

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http://research.google.com/pubs/HannesPayer.html