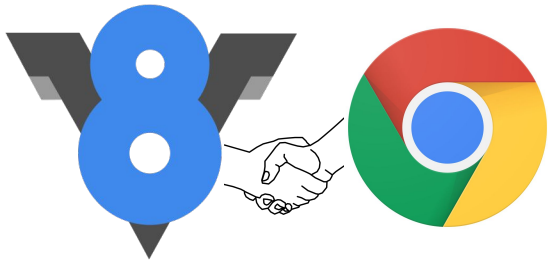
Garbage Collection as a Joint Venture



Michael Lippautz

Ulan Degenbaev, Jochen Eisinger, Kentaro Hara, Marcel Hlopko, Hannes Payer
Google Inc

MoreVMs Workshop, Brussels, 2017

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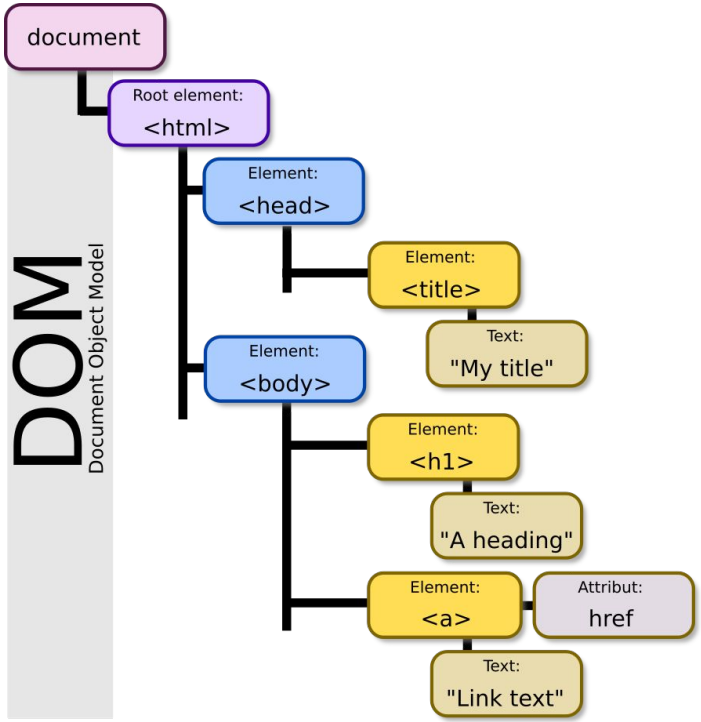
The Web, JavaScript, and Chrome

Web - JavaScript - Chrome

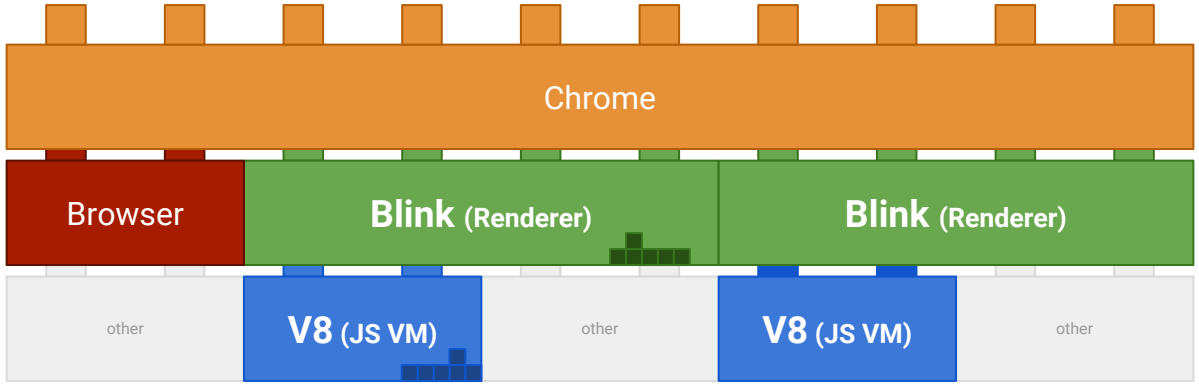


- Document Object Model (DOM)
- Cross-platform language-independent representation of HTML
- Web Interface Definition Language (IDL)
- Traditionally encoded as objects in the rendering engine (e.g. Blink)

Web - JavaScript - Chrome

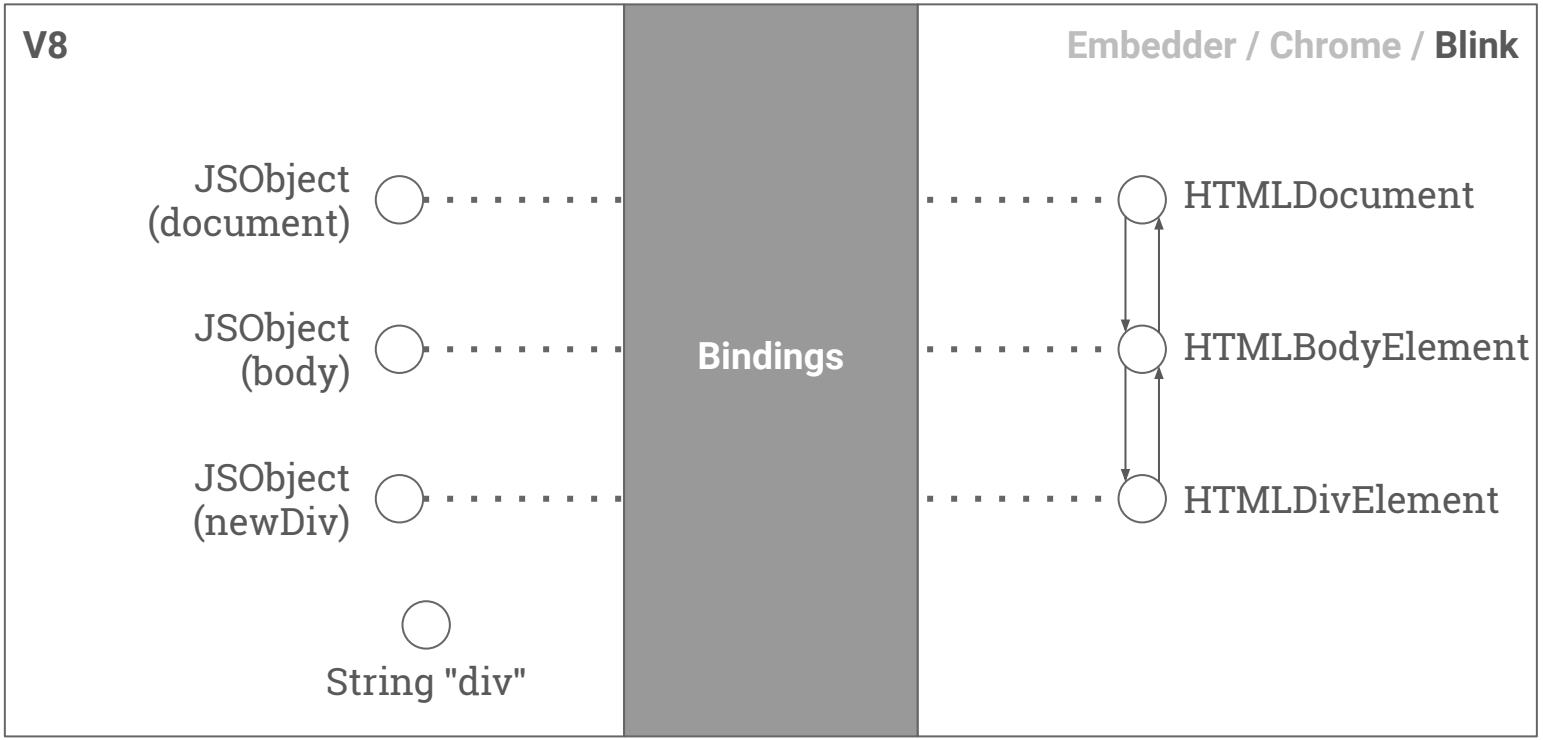
```
<script type="text/javascript">
  var newDiv;
  function createDiv() {
    newDiv = document.createElement("div");
    document.body.appendChild(newDiv);
  }

  window.onload = createDiv;
</script>
```

Web - JavaScript - Chrome at runtime



Idea: Abstraction of the browser into components
(and most of the time subcomponents)

Web - JavaScript - Chrome



Bindings: Gluing together V8 and Blink

V8

- Managed heap for JavaScript objects
- Dynamic object layout (shape changes)
- Precise GC
- Mark-Sweep-Compact Collector
  - Incremental marking
  - Concurrent sweeping
  - Parallel compaction

Blink

- Managed heap for (most of) the DOM
- Static object layout
- Precise and conservative GC (until Q1’16 ref counting)
- Stop-the-world Mark-Sweep(-Compact) Collector
  - Incremental sweeping
  - (Compaction on backing stores of collections)

Bindings: Gluing together V8 and Blink

V8

- Managed heap for JavaScript objects
- Dynamic object layout (shape changes)
- Precise GC
- Mark-
  -
  -
  - Parallel compaction

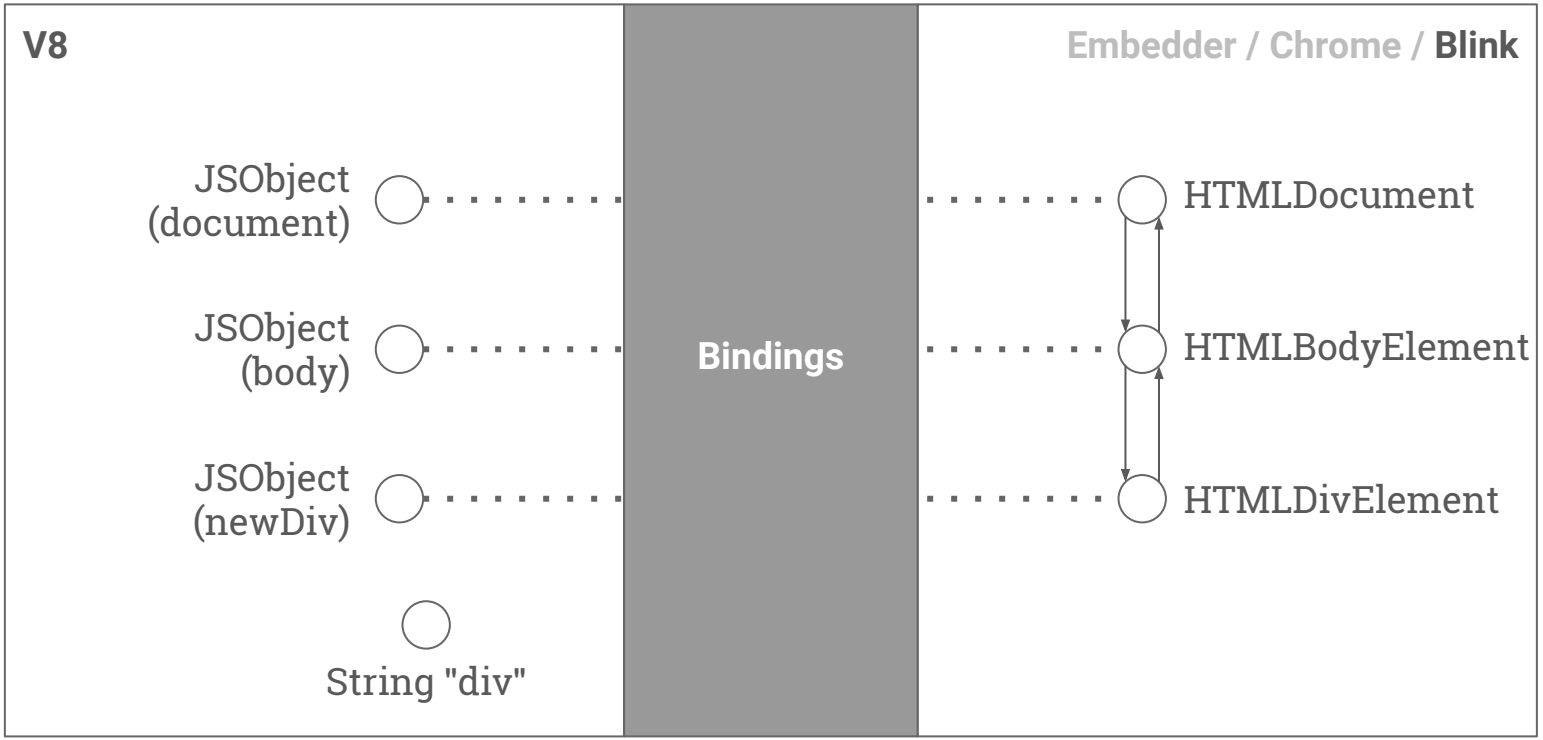
Blink

- Managed heap for (most of) the DOM
- Static object layout
- Precise and conservative GC (until Q1’16 ref
  - npact)
  - Incremental sweeping
  - (Compaction on backing stores of collections)

Two very different systems communicating with each other!

The Cycle Problem

The Cycle Problem



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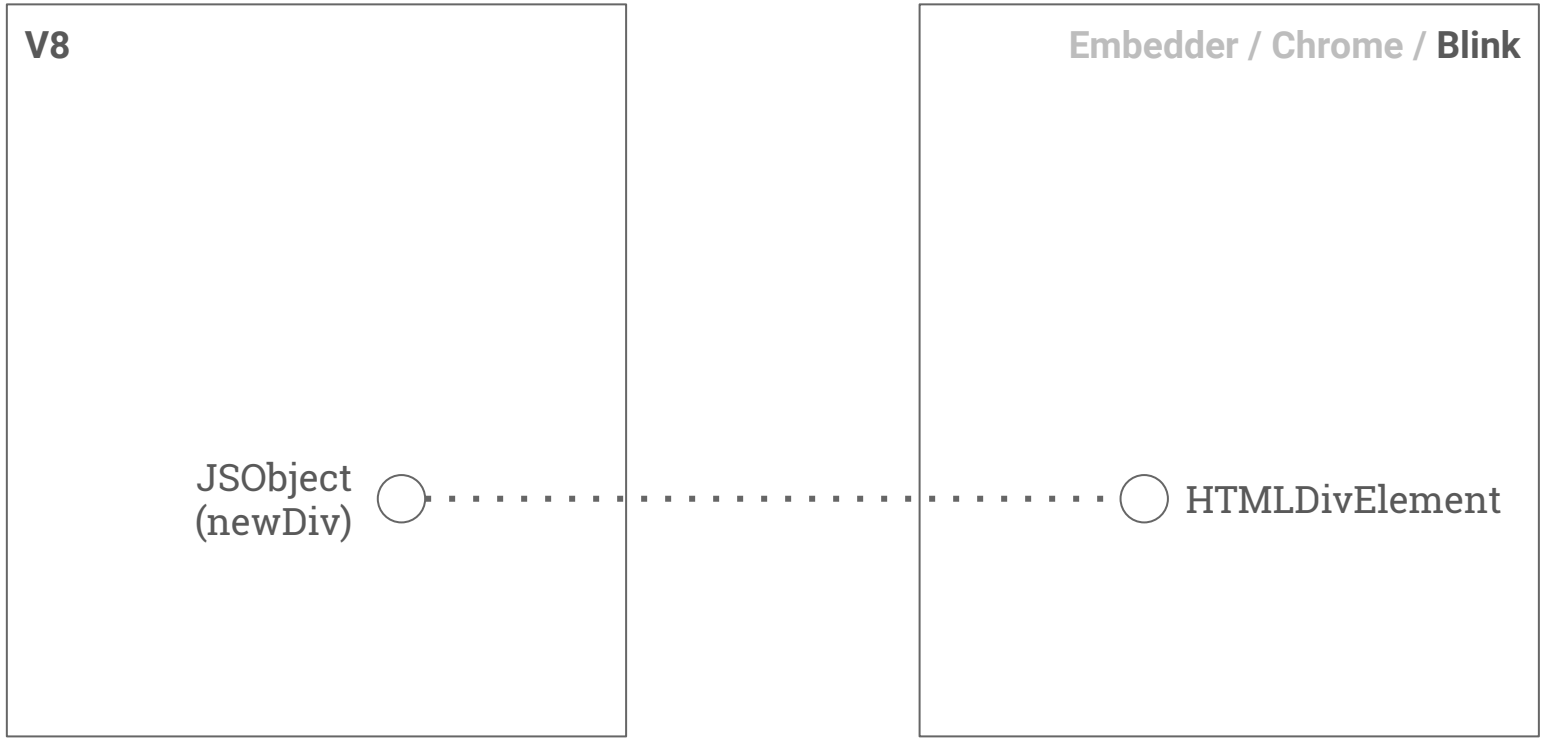

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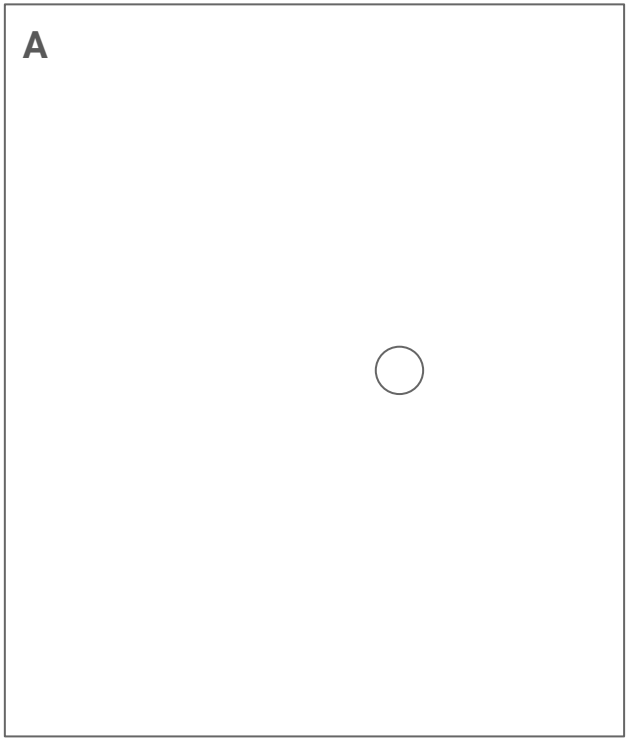

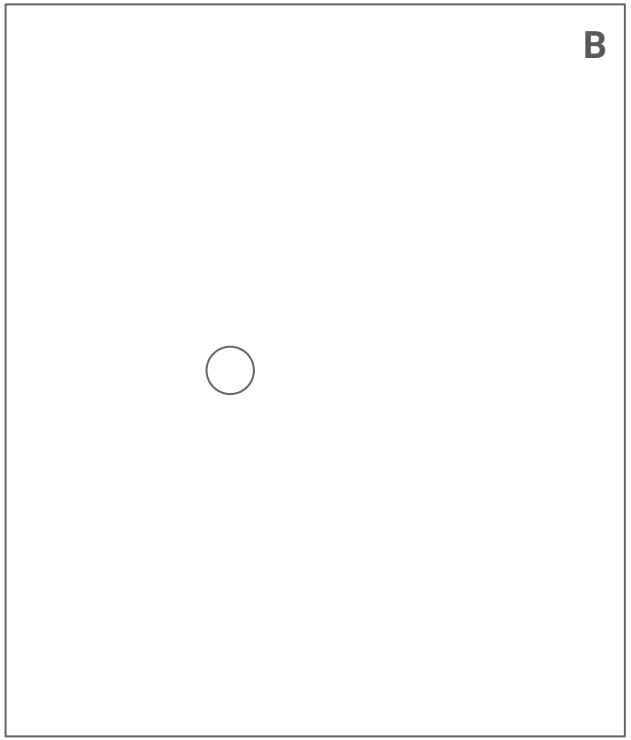

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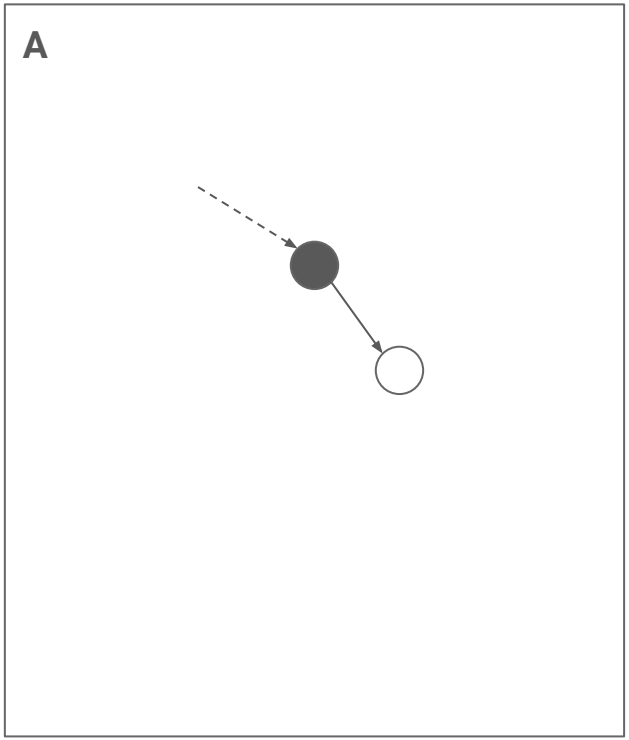

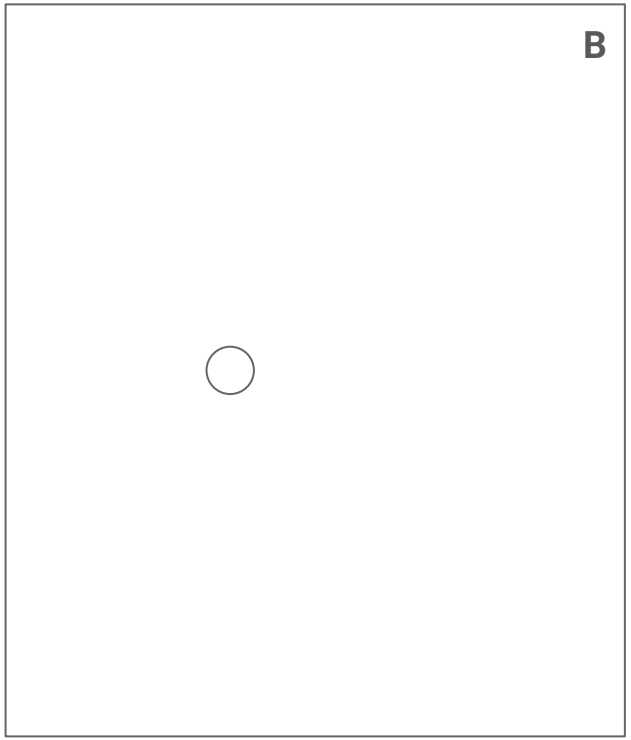

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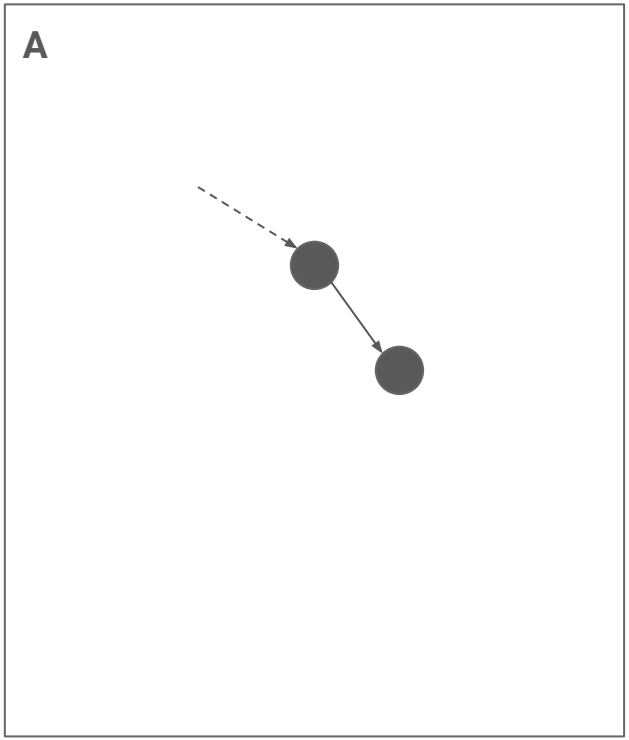

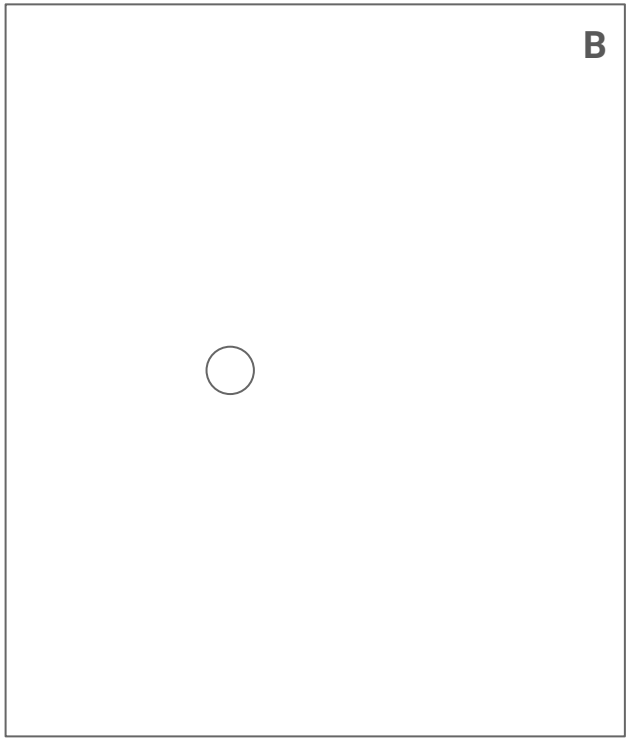

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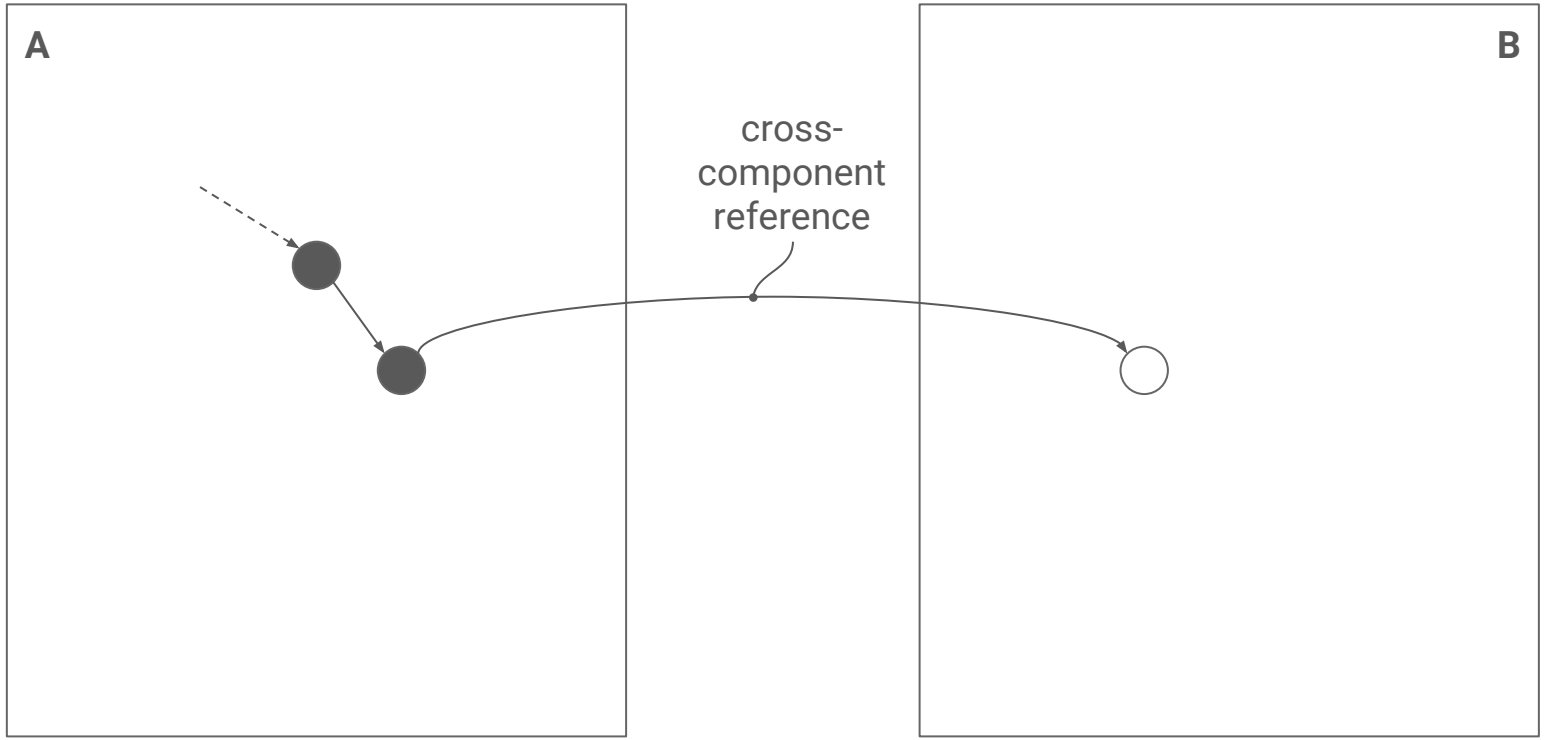

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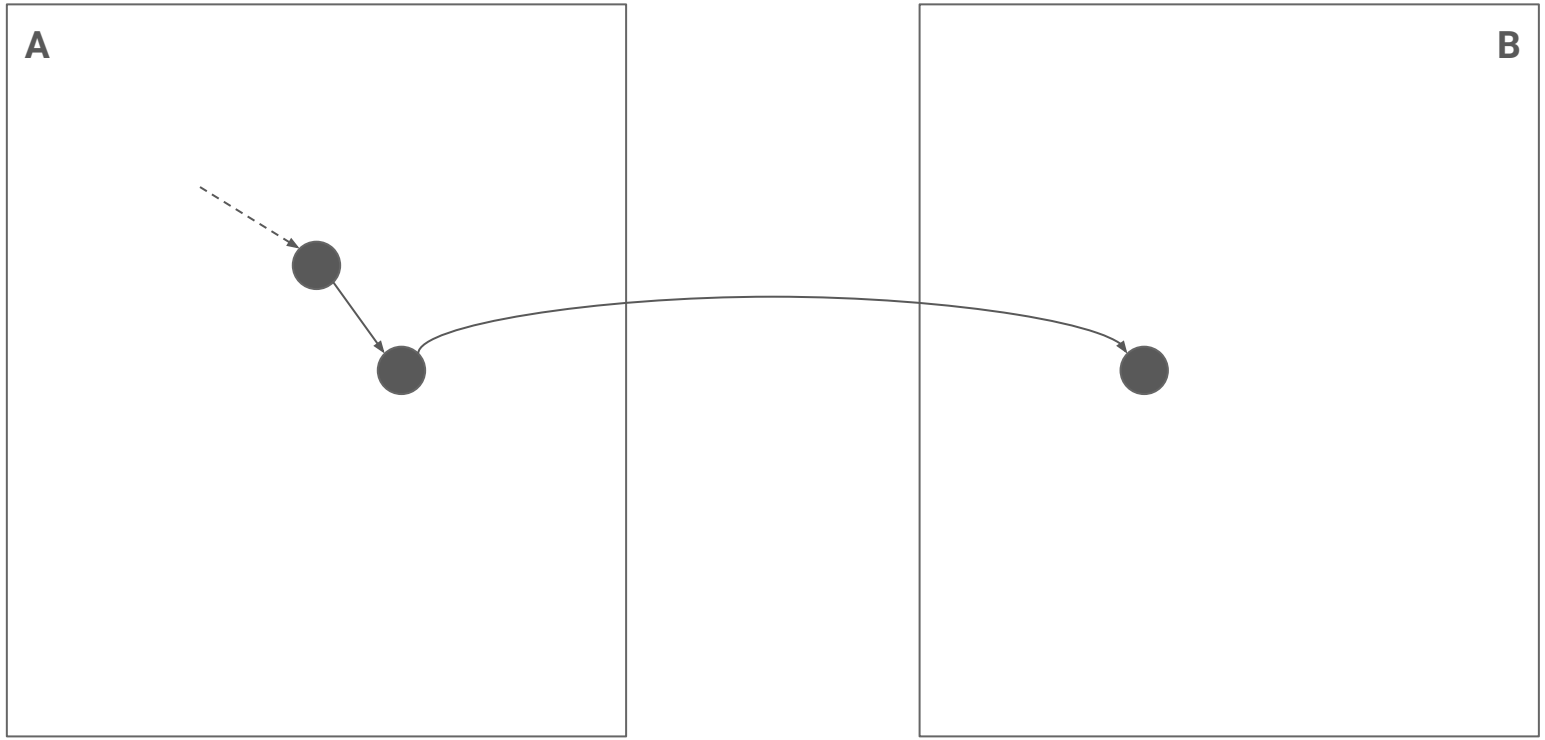

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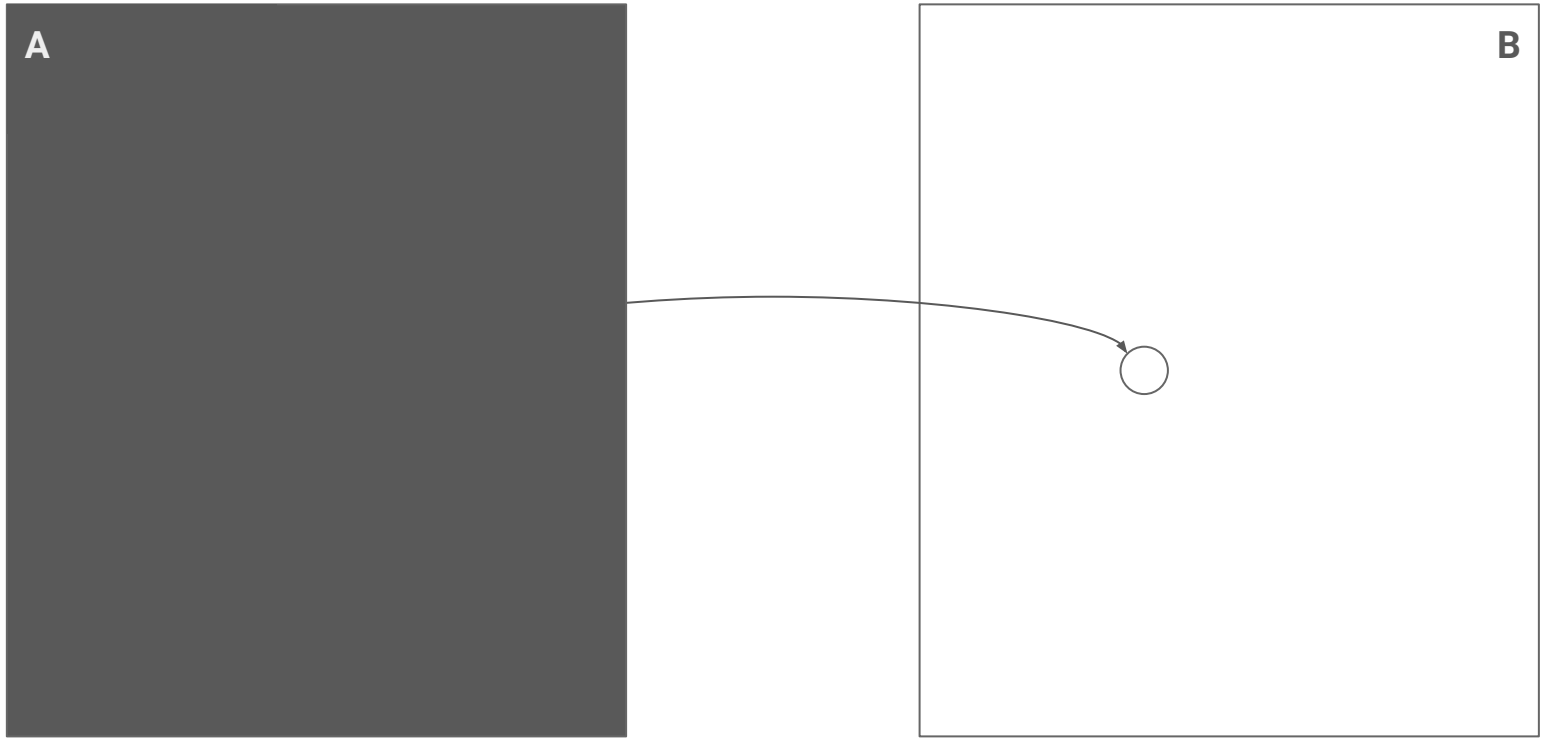

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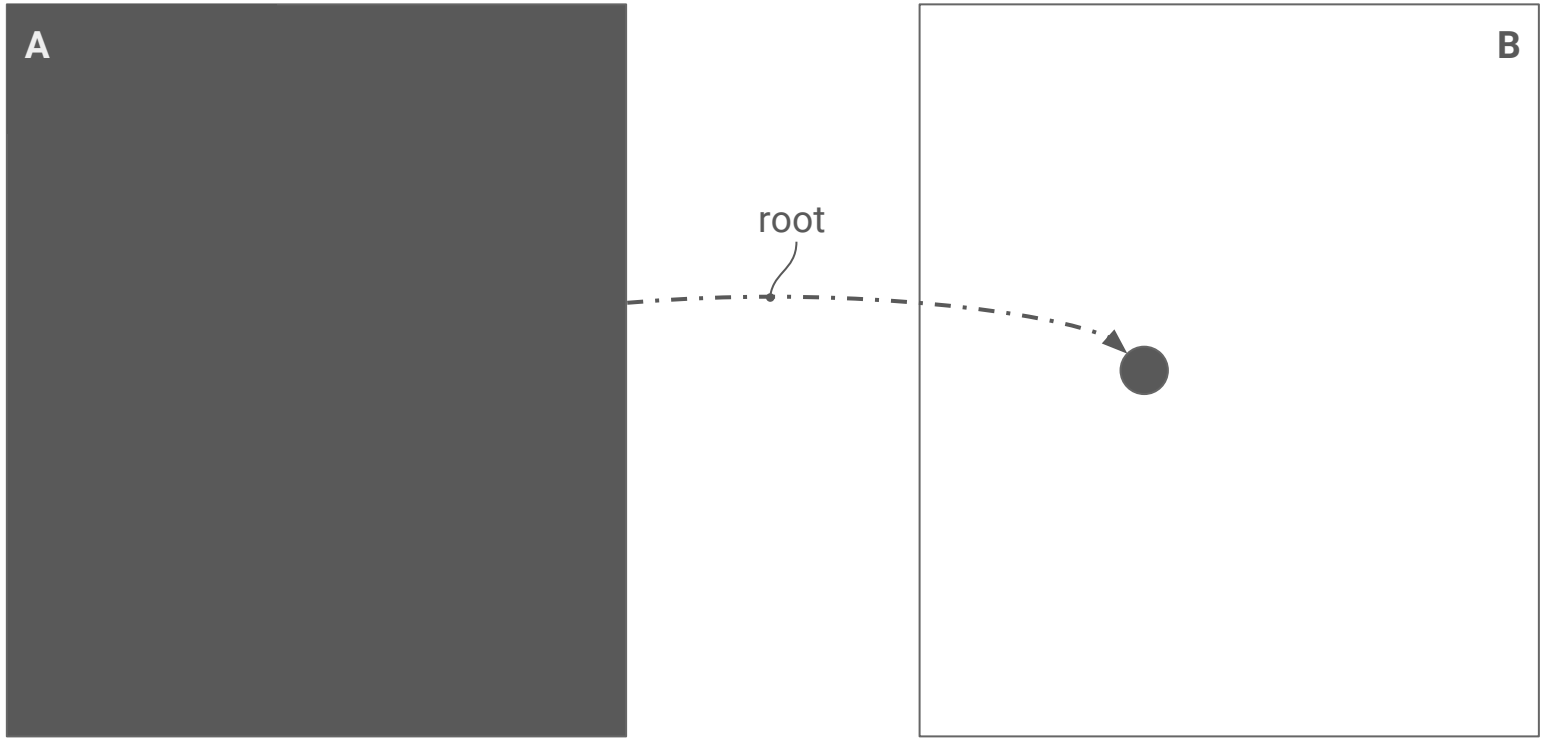

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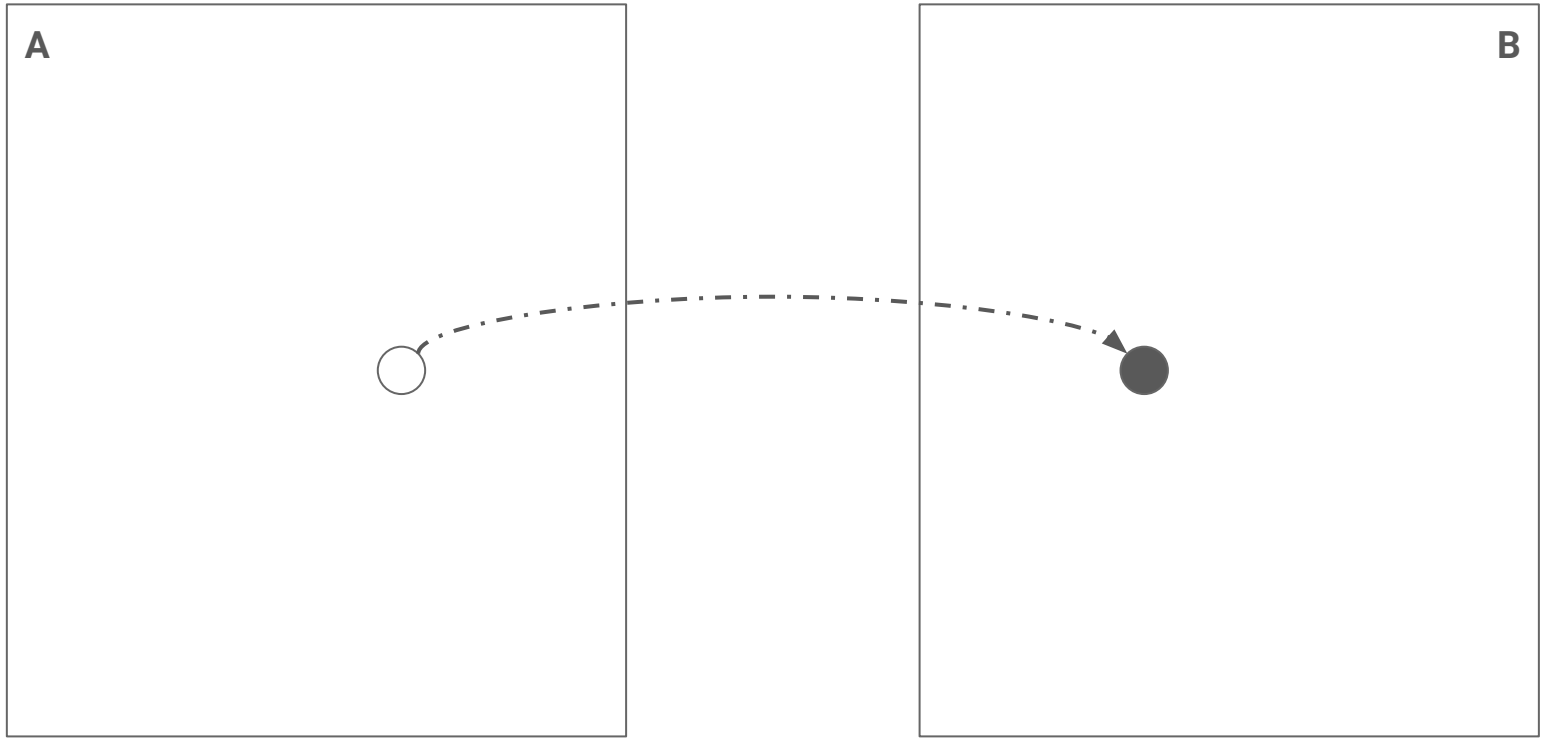

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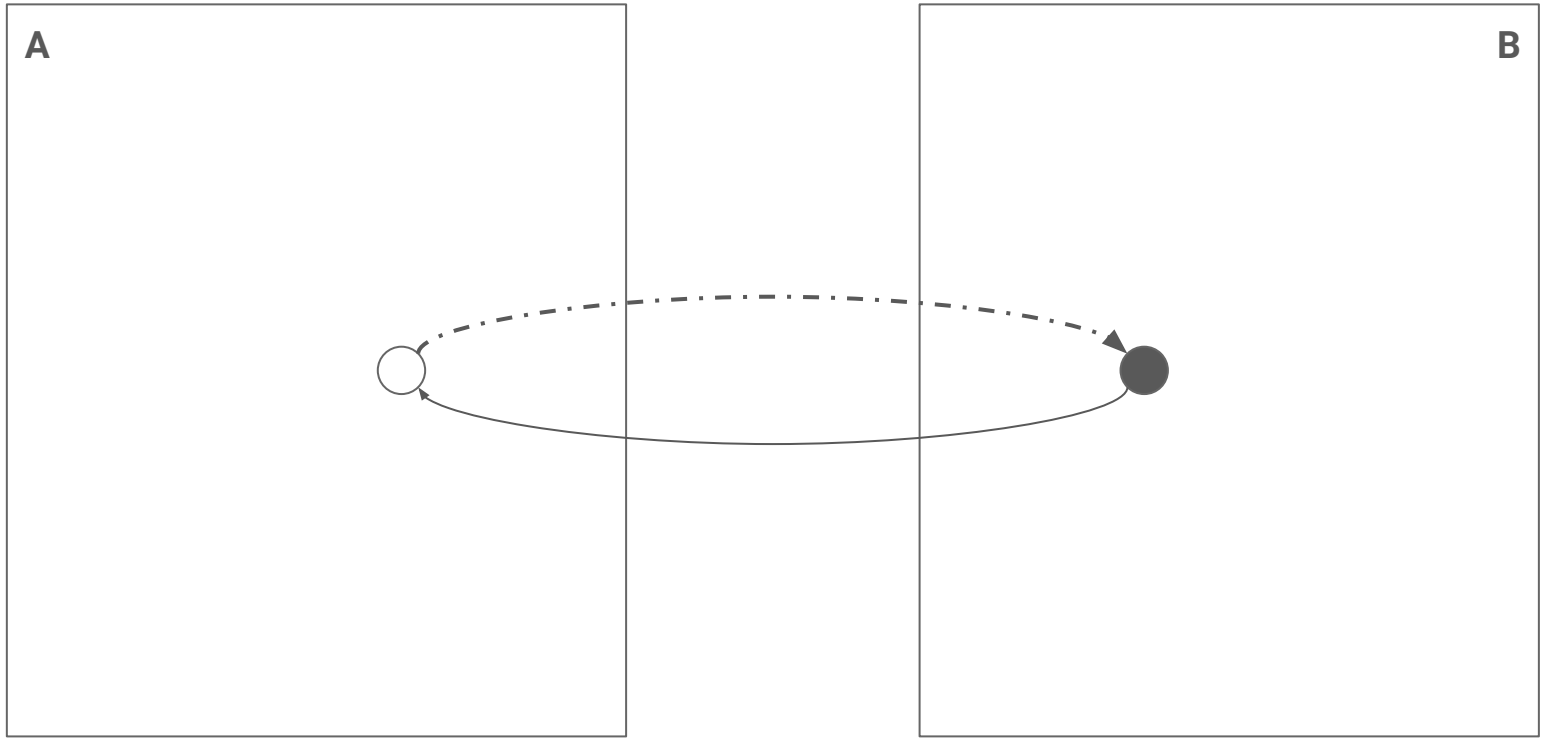

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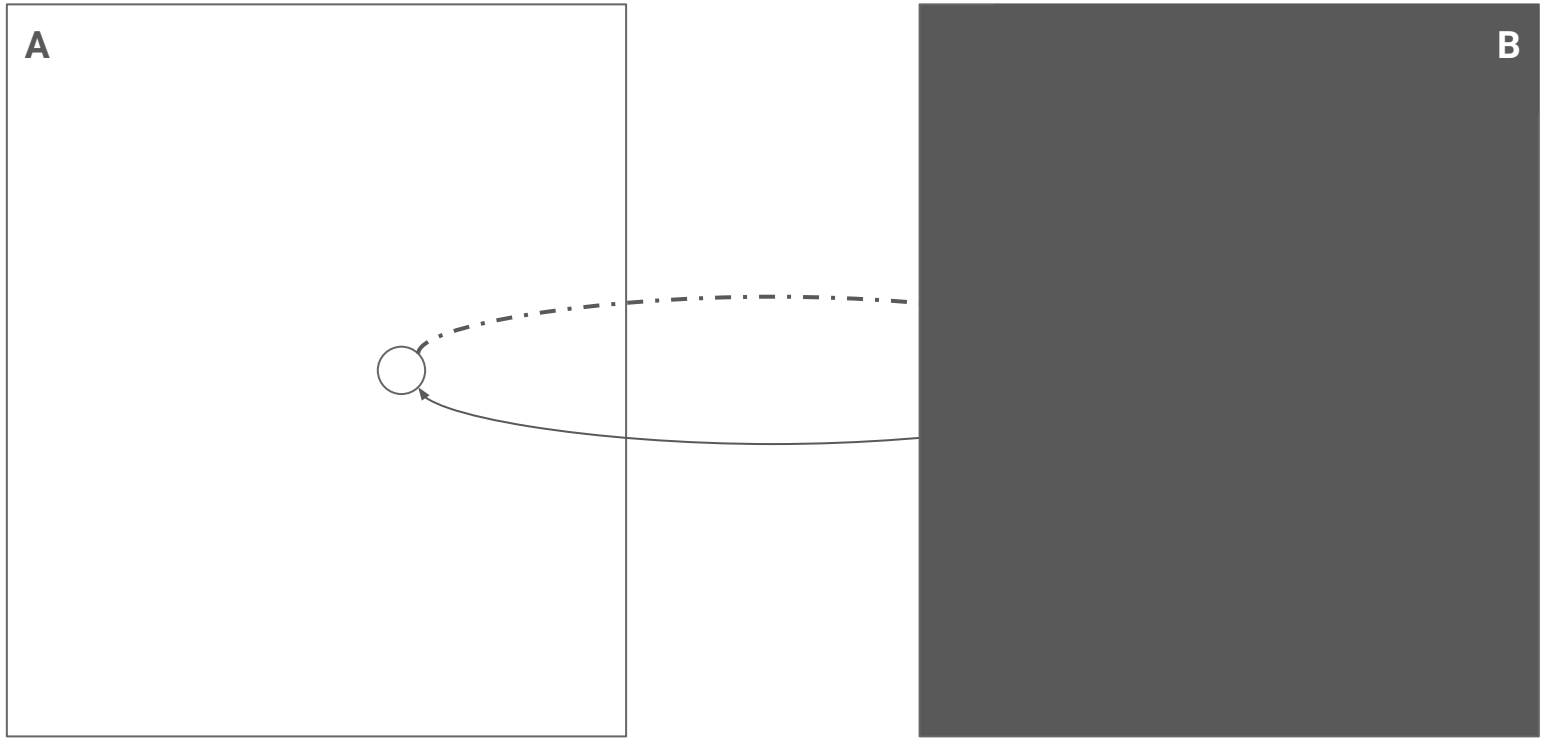

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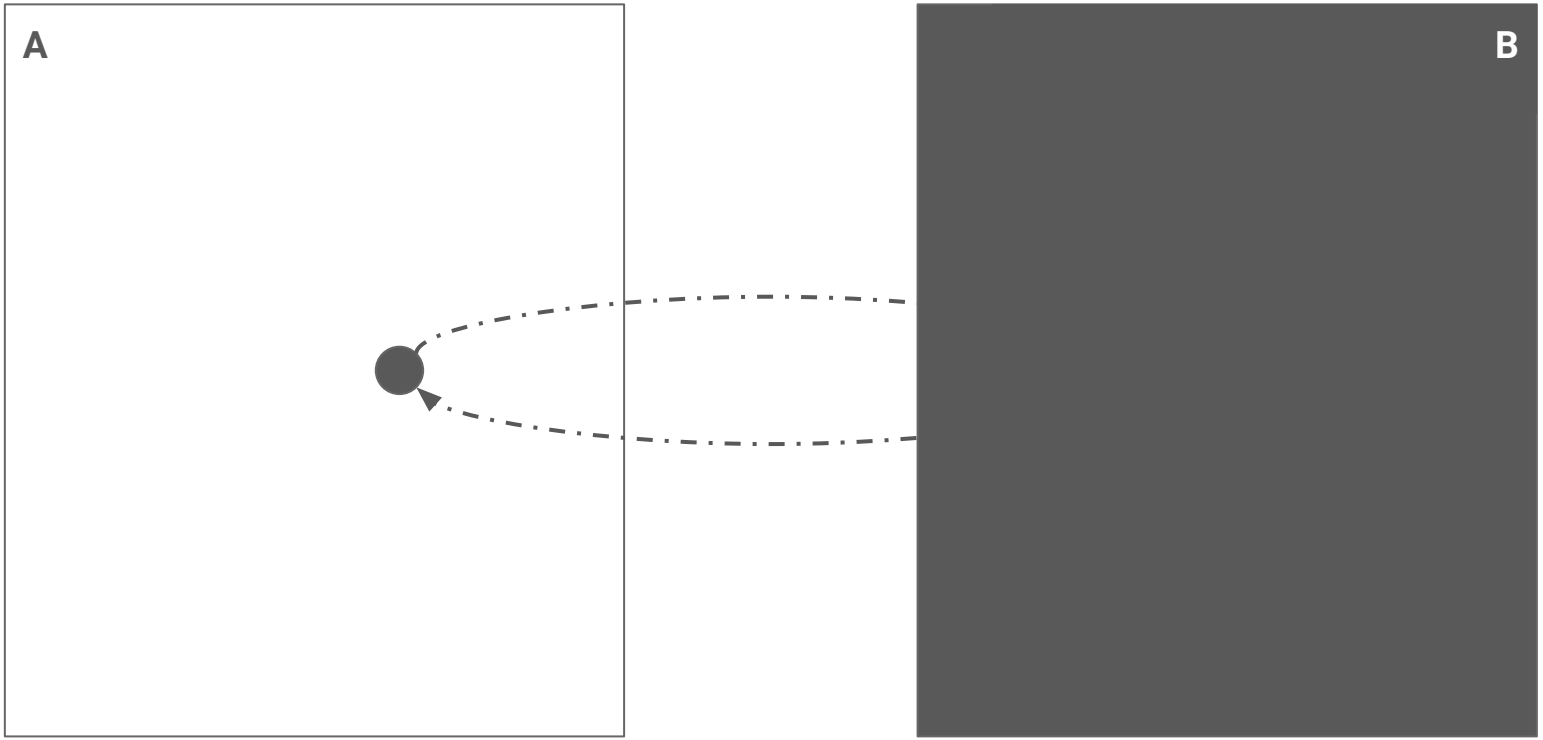

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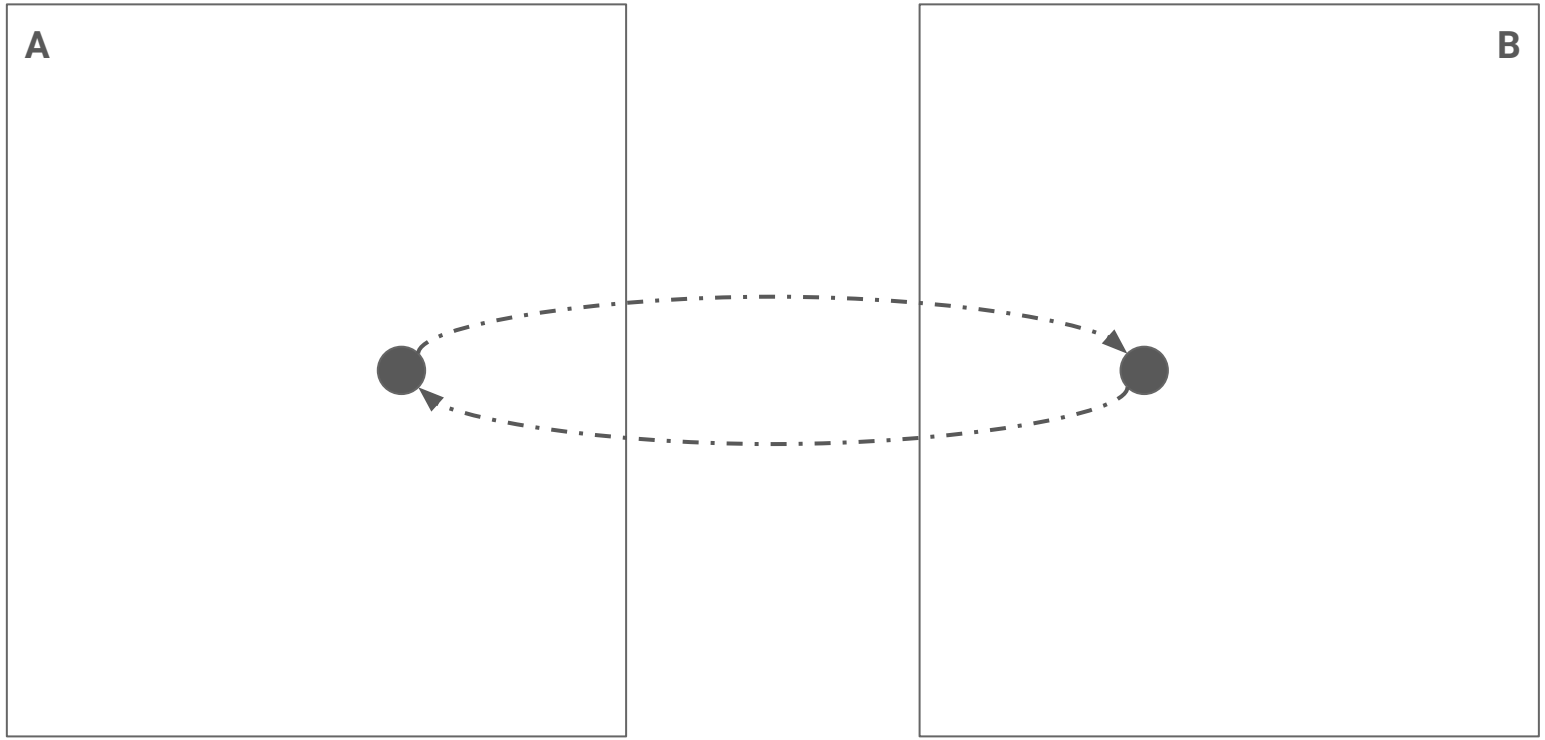


The Cycle Problem

- Manual breaking of cycles using weak references
  - Not possible when cross-component reference requires object to stay alive

Observations

- Similar to cycle problem when using reference counts
  - Lots of algorithms and literature on how to deal with cycles
- Cross-component information required to break cycles automatically

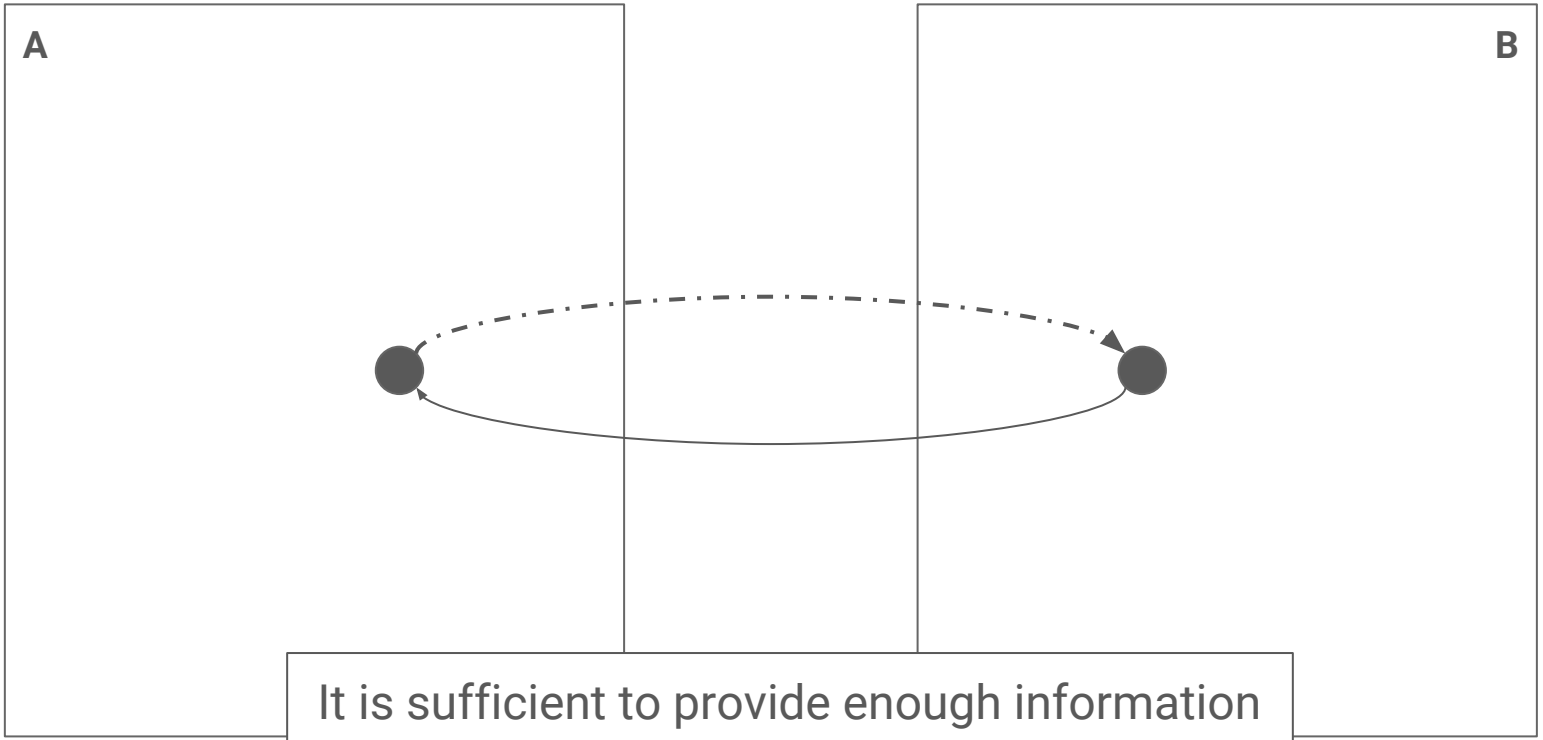
Cross-Component Garbage Collection

Cross-Component Garbage Collection

Provide and process liveness information

across components boundaries

Cross-Component Garbage Collection



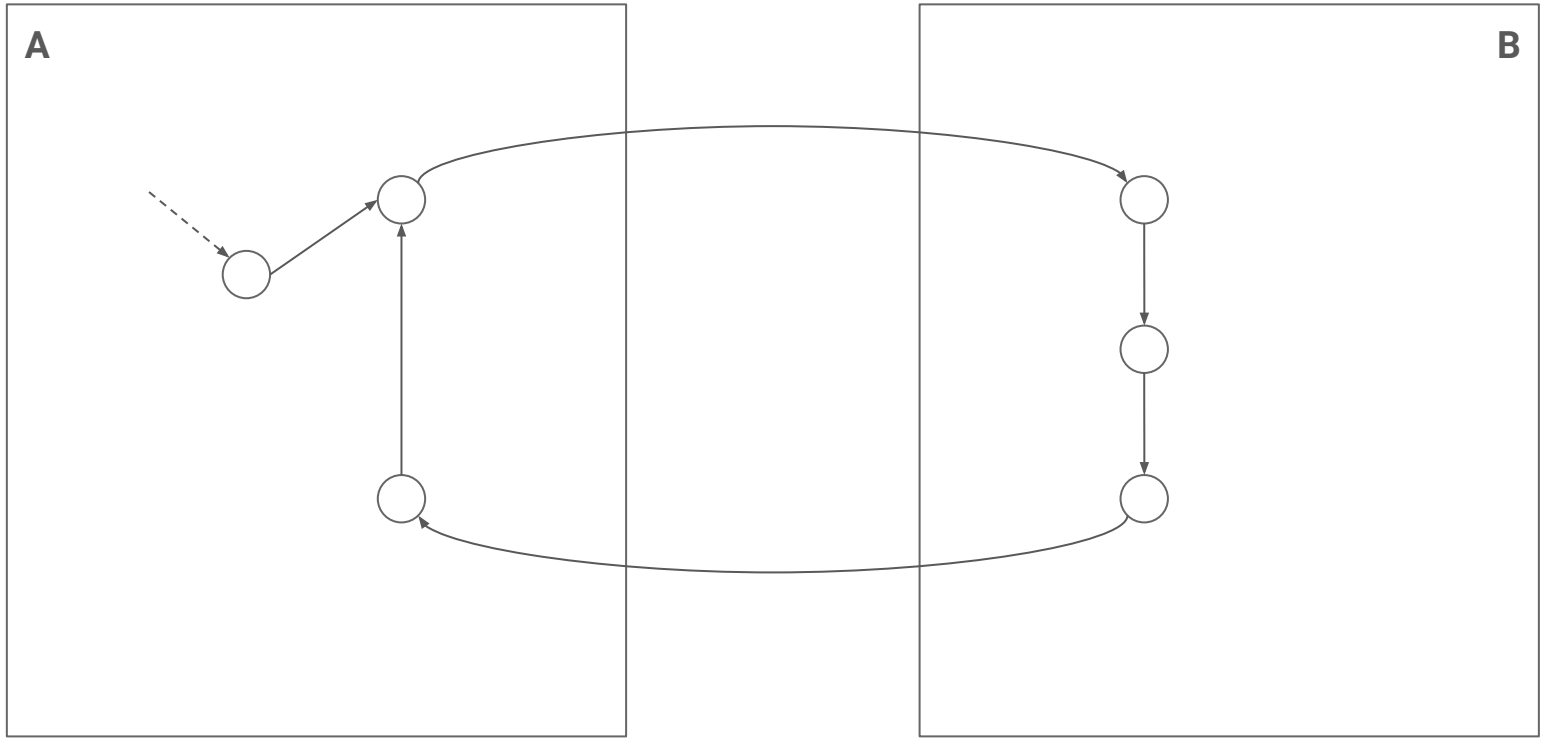
It is sufficient to provide enough information to break one link of the cycle

Tracing across component boundaries

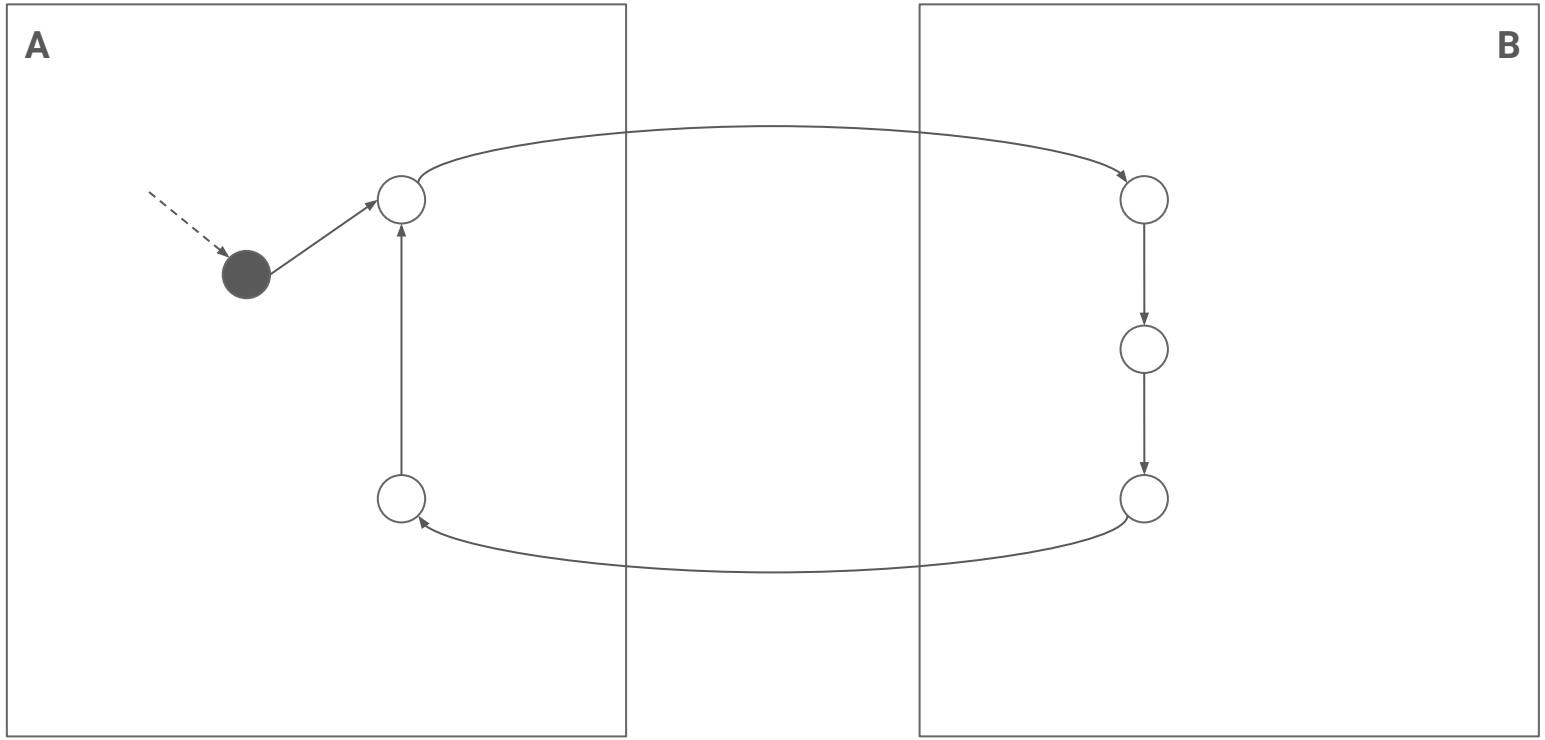
trace :: Object -> [Objects]

Return all objects that are transitively reachable from a given object

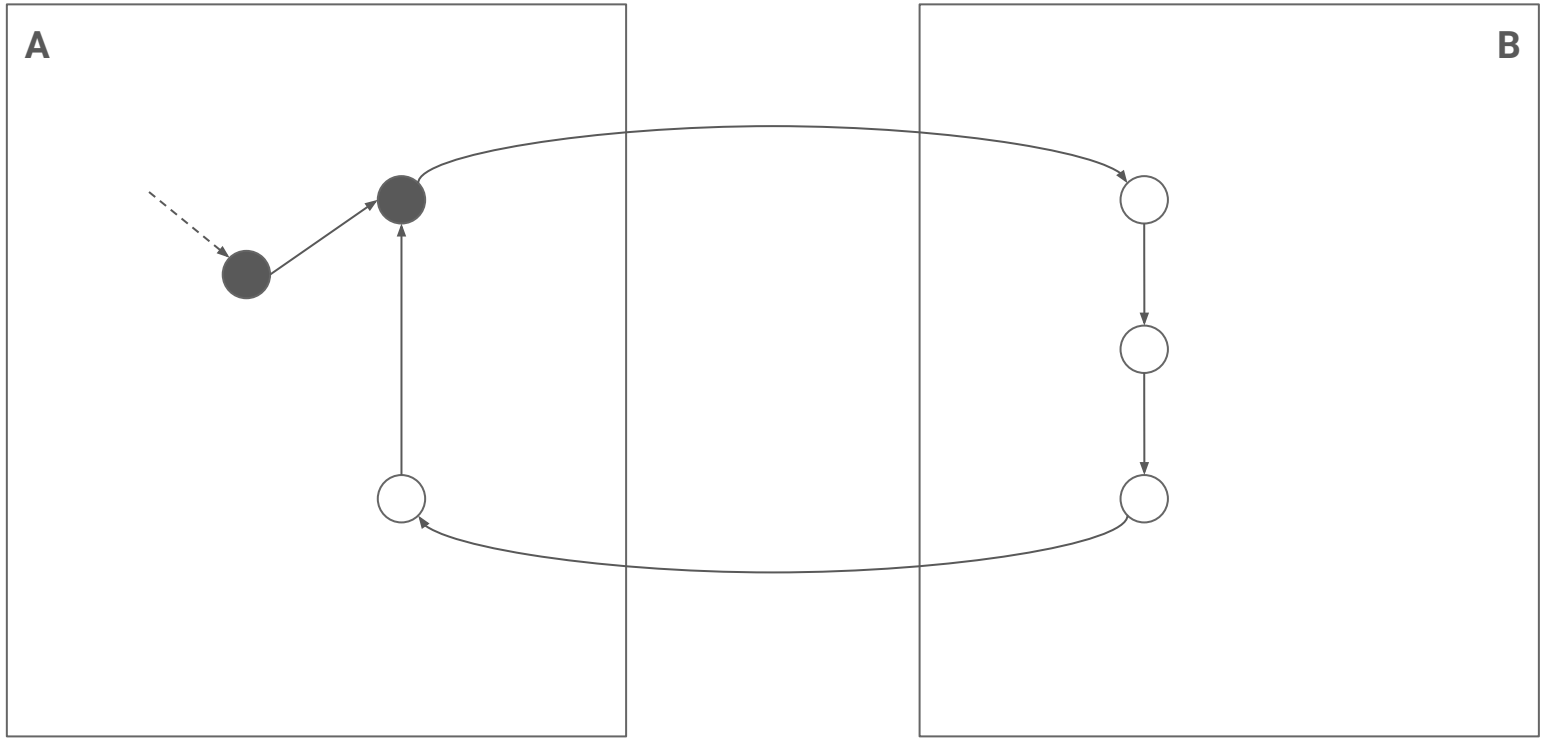
Tracing across component boundaries



Tracing across component boundaries



Tracing across component boundaries



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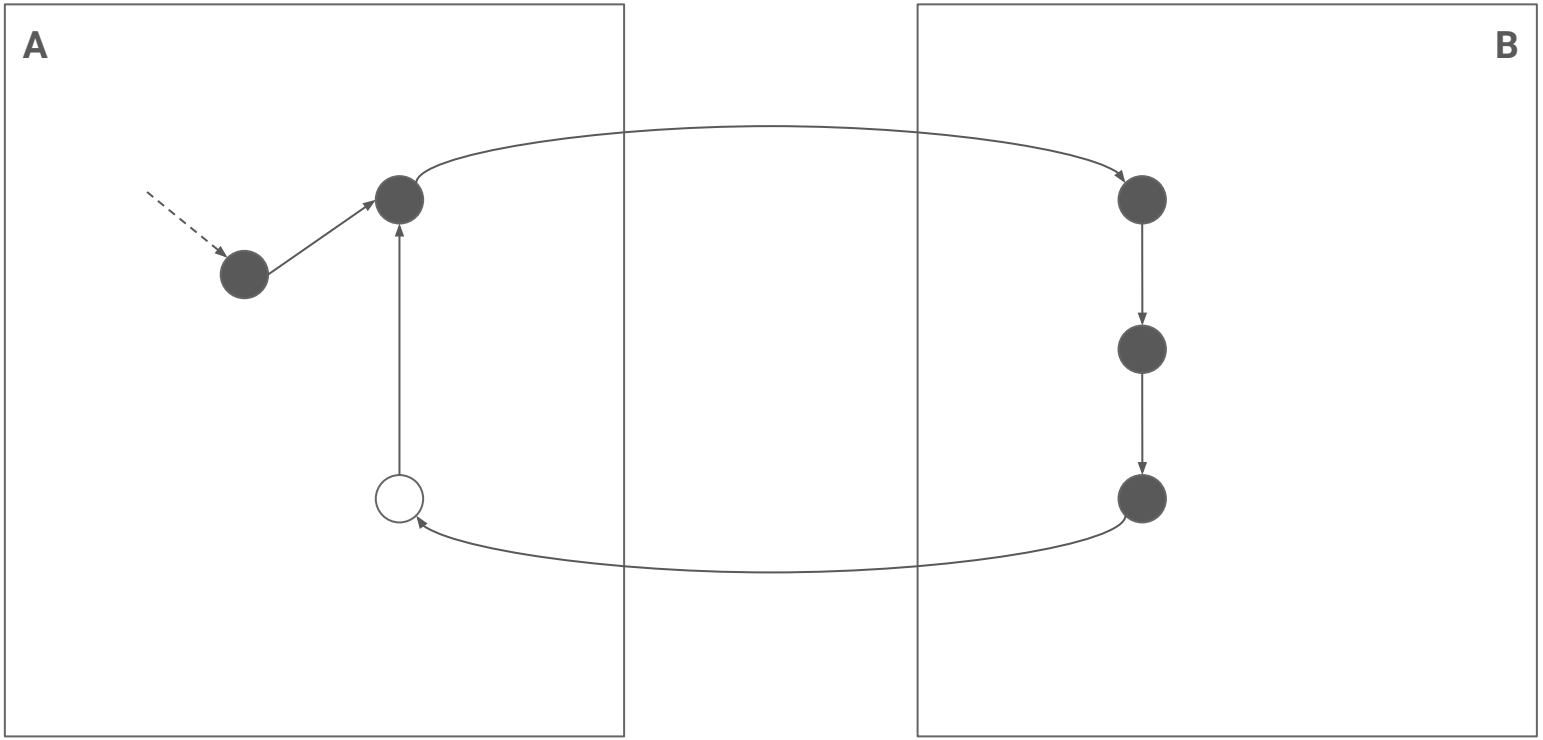

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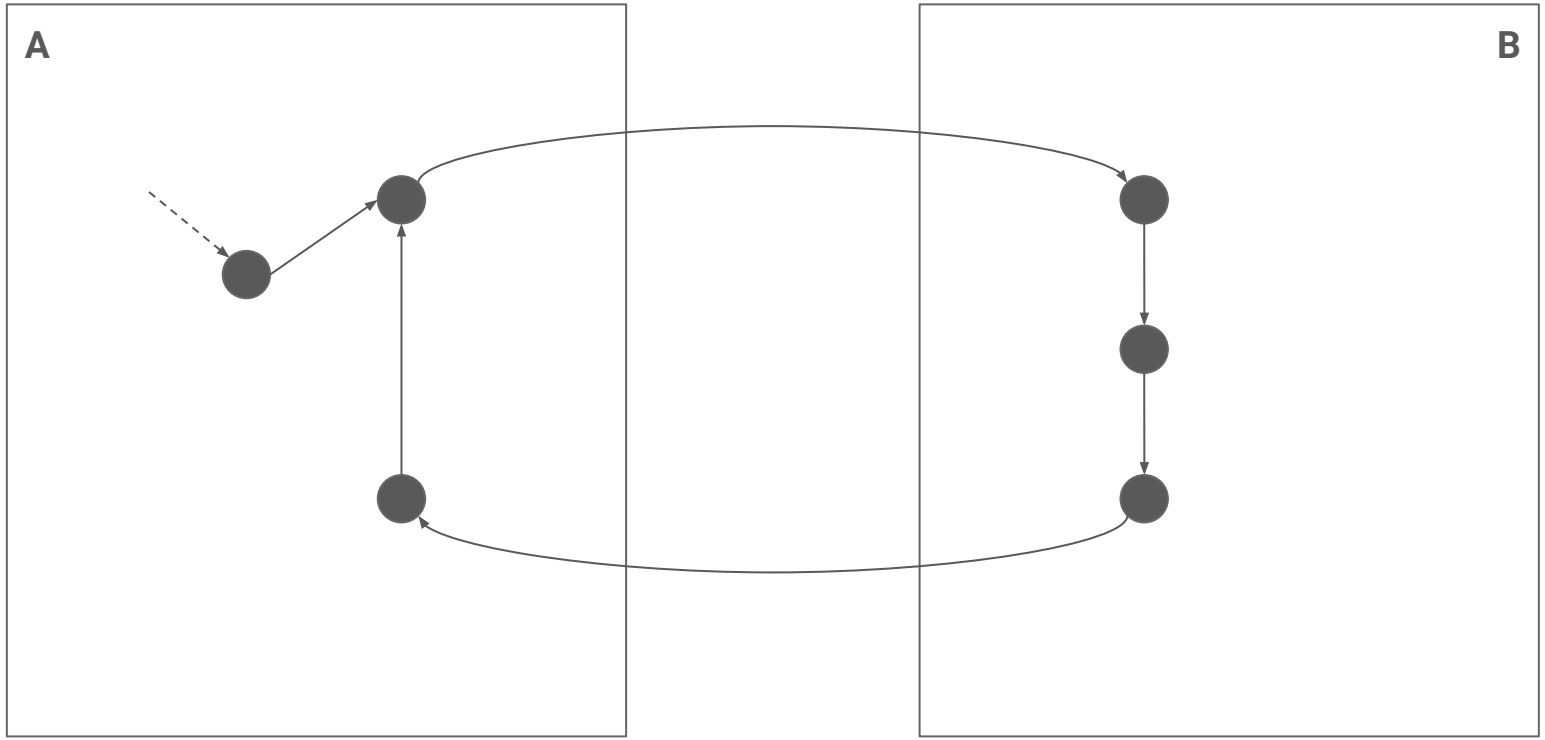


V8: Tracing from JavaScript to C++ and back

- Batch-based communication
- Control over when to start tracing

V8 exposes an interface that embedders need to implement

RegisterReferences([Object])

Allows communicating objects that are entry points into the embedders heap

RegisterExternallyReferencedObject(Object)

Communicate that Object is reachable through some entry point object

AdvanceTracing(deadline, force_completion)

Trace objects on the embedder's heap

Interlude: Incremental Marking

- Main thread gets interrupted and marks *n* objects until all live objects are marked
- Ingredients:
  - One marking deque
  - Three colors
    - White: unknown
    - Grey: on marking deque and will be processed
    - Black: marked
  - Barriers ensuring consistency
  - A driver that ensures marking progress

Blink: Write Barrier

- Preserving strong tri-color invariant
  - No black to white edges
- Dijkstra-style write barrier

```
write(Object source, Object value):
  if (is_tracing && is_marked(source) && !is_marked(value))
    mark(value)
    marking_deque.push(value)
```

Correctness: C++ Write Barriers

Key problem: Not emitting the write barrier

- Idea: Rely on C++ type system to enforce the barriers
- GC pointers: GC-aware smart pointers
  - Back pointer to object header
  - Emit barrier on write, (copy) construction, move
- Restrict tracing methods to accepting only those GC pointers
  - Result: Compile failure if raw pointers are used

Successfully annotated ~**250** fields in the DOM that required a barrier

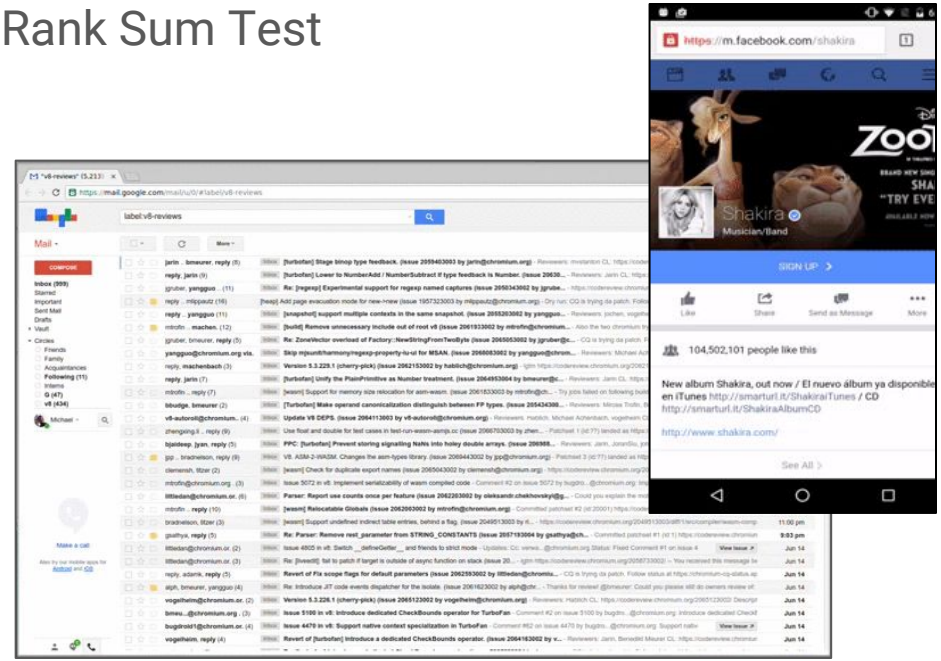
Benchmarking / Results

Baseline: Object Grouping

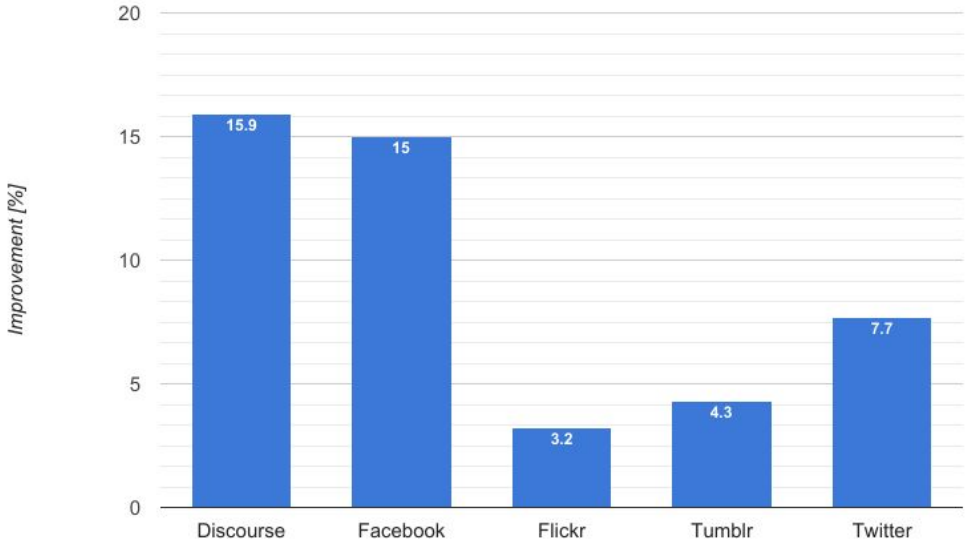
- Objects are grouped together based on rules, e.g., DOM tree
- A group is considered as live if one object of the group is alive
- Incremental over approximation possible but expensive
  - Needs to consider live and dead objects
- Prone to memory leaks in certain situations

Benchmarking

- Real-world workloads using Catapult benchmarking framework
- Trace every single GC event, e.g. marking, marking finalization, atomic pause
- Hypothesis testing using Wilcoxon Rank Sum Test



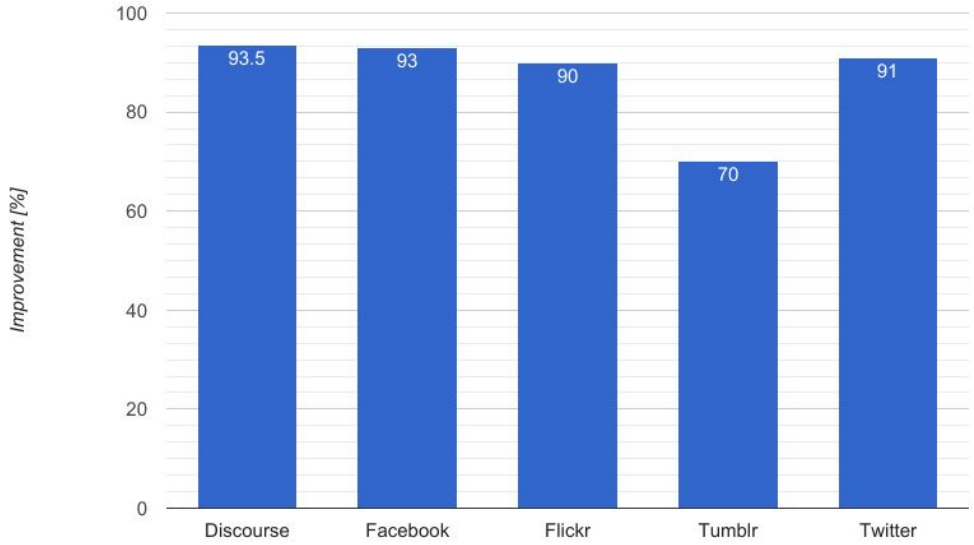
Average Latency-critical GC Pause



Wilcoxon Rank Sum Test	**significant**	**significant**	**not significant**	**not significant**	**significant**

Incremental Marking Finalization

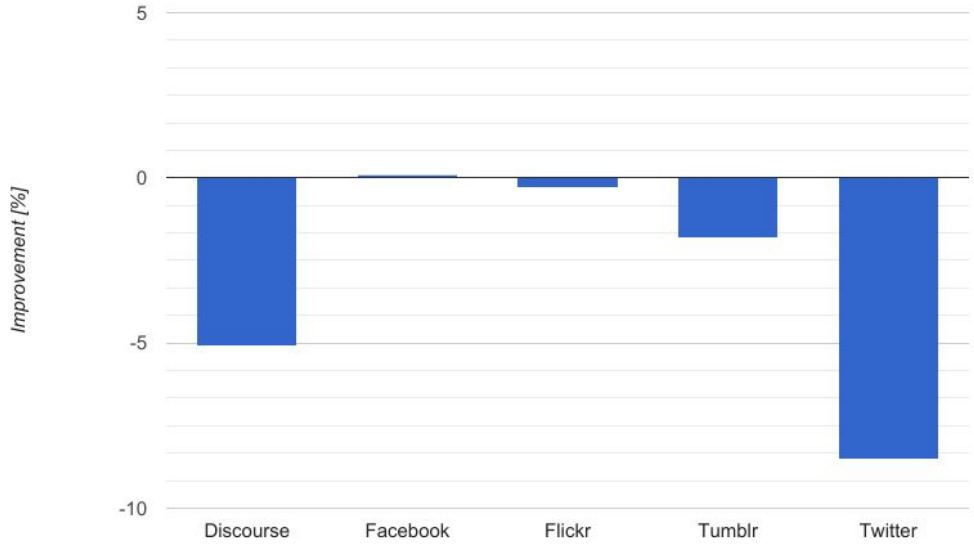
Potentially last incremental step before atomic pause



Wilcoxon Rank Sum Test	**significant**	**significant**	**significant**	**significant**	**significant**

Marking Time

the tradeoff



Wilcoxon Rank Sum Test	**significant**	**not significant**	**not significant**	**not significant**	**significant**

Google

Fin. Thank you!

chromium.org

v8project.org