EventRacer: Finding Concurrency Errors in Event-Driven Applications

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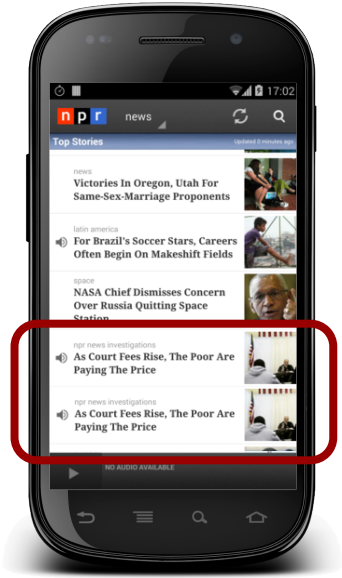
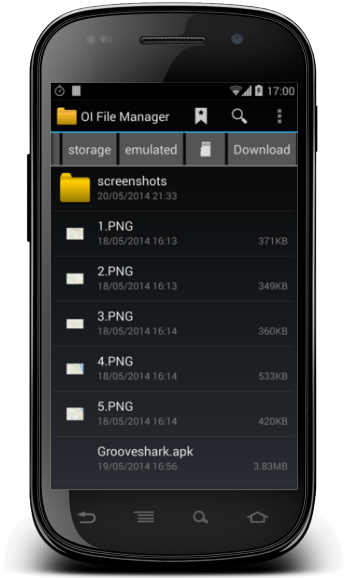
SRL
SOFTWARE RELIABILITY LAB

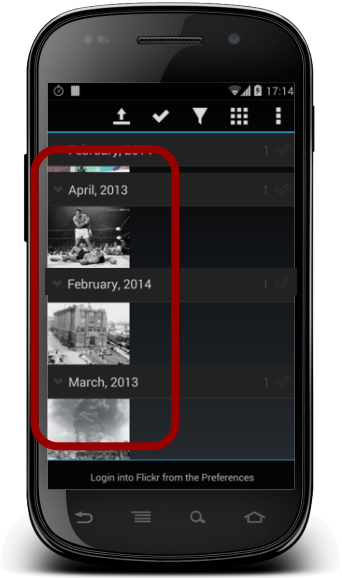
Android Errors Caused by Concurrency



Display article twice



Display wrong directory



Display wrong order

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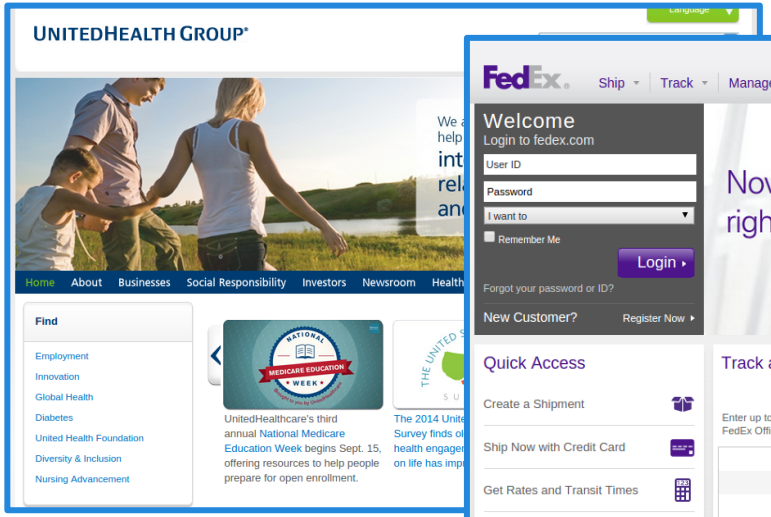
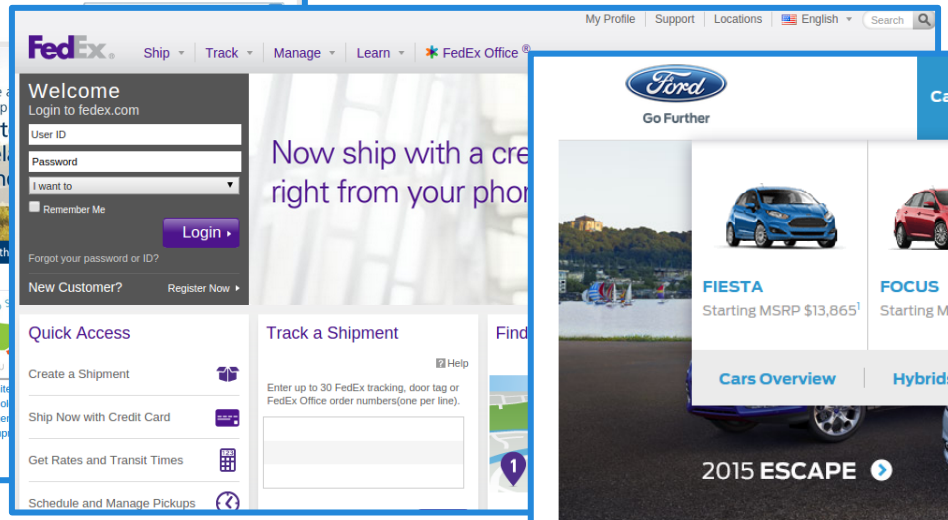
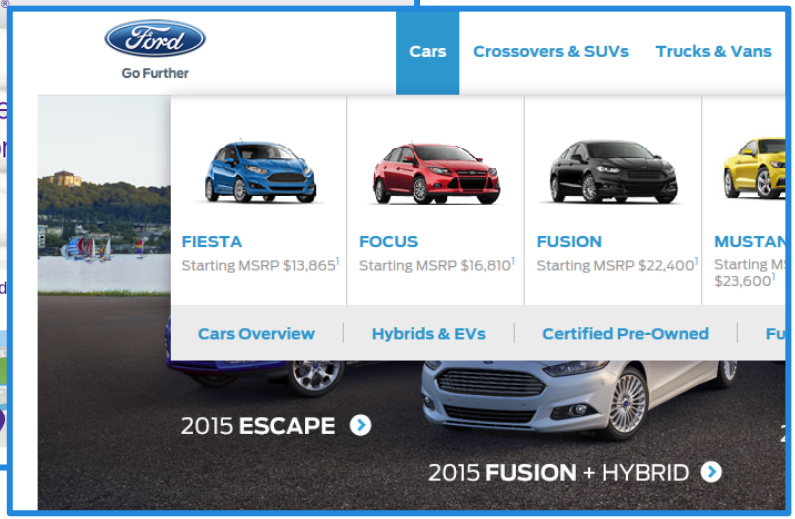
Web Page Errors Caused by Concurrency



Incomplete form submitted



jQuery version used non-deterministically



Non-operational menu

Event-Driven Applications

designed to hide latency, various asynchronous APIs

network, disk, database, timers, UI events

highly asynchronous and complex control flow

scheduling non-determinism

asynchrony is not intuitive

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Trouble with Asynchrony

stackoverflow

- Background task, progress dialog, orientation change - is there any 100% working solution?
- JavaScript function sometimes called, sometimes not
- Avoiding race conditions in Google Analytics asynchronous tracking
- Ajax Call Sometimes Works, Sometime works and refreshes, Sometimes refreshes and fails ...?
- Is AsyncTask really conceptually flawed or am I just missing something?

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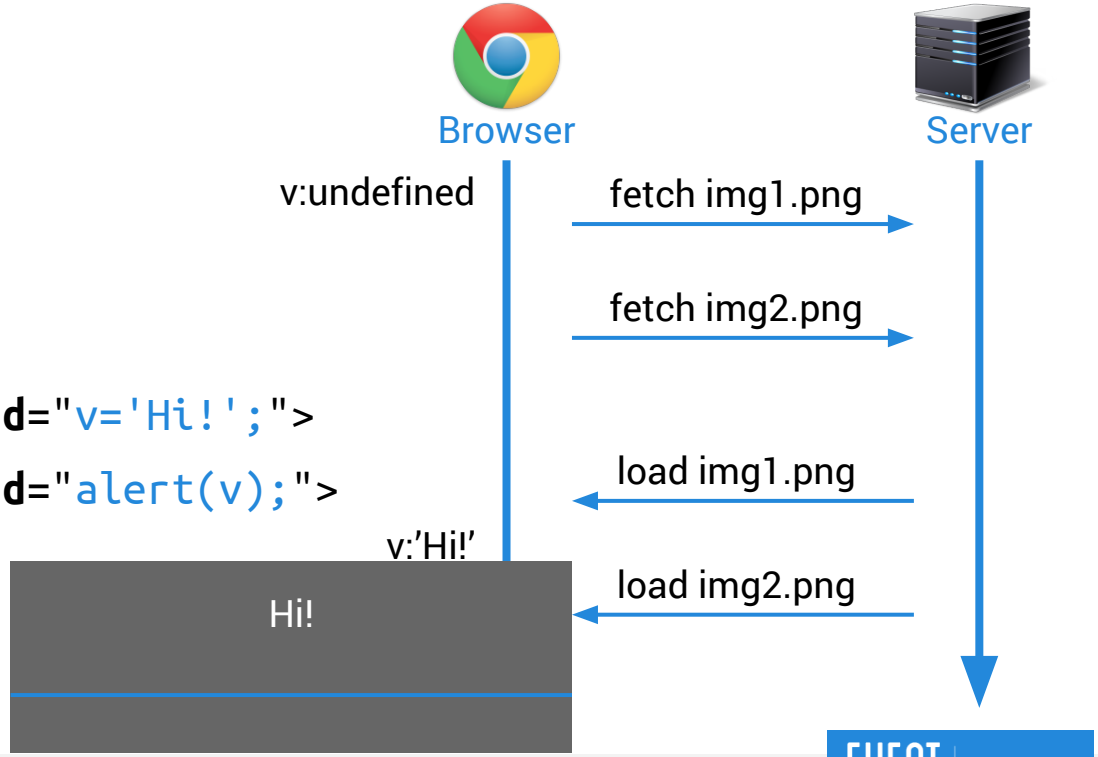
“Hello World” of web page concurrency

```
<html><body>
<script>
var v=undefined;
</script>

<img src="img1.png"    onload="v='Hi!';">
<img src="img2.png"    onload="alert(v);">


</body></html>
```

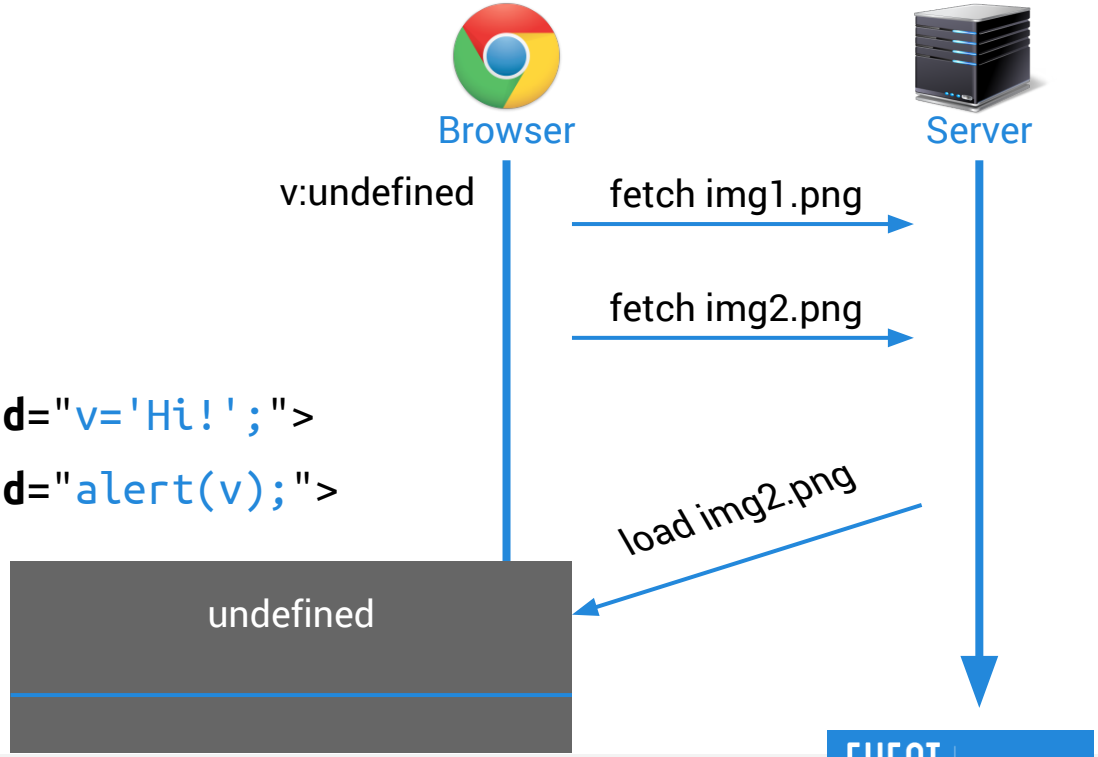


Bad interleaving

```
<html><body>
<script>
var v=undefined;
</script>

<img src="img1.png"    onload="v='Hi!';">
<img src="img2.png"    onload="alert(v);">


</body></html>
```



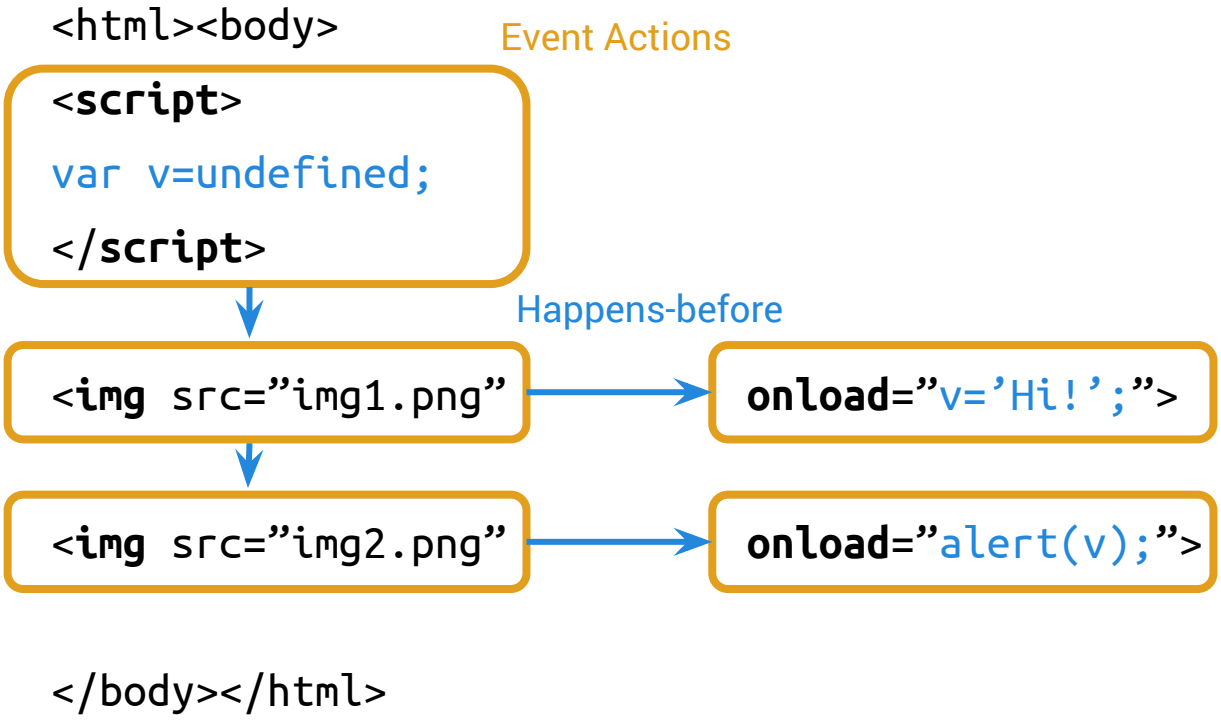
Understanding the problem

```
<html><body>
<script>
var v=undefined;
</script>
<img src="img1.png"
<img src="img2.png"
</body></html>
```

Event Actions

```
onload="v='Hi!';">
onload="alert(v);">
```

Understanding the problem



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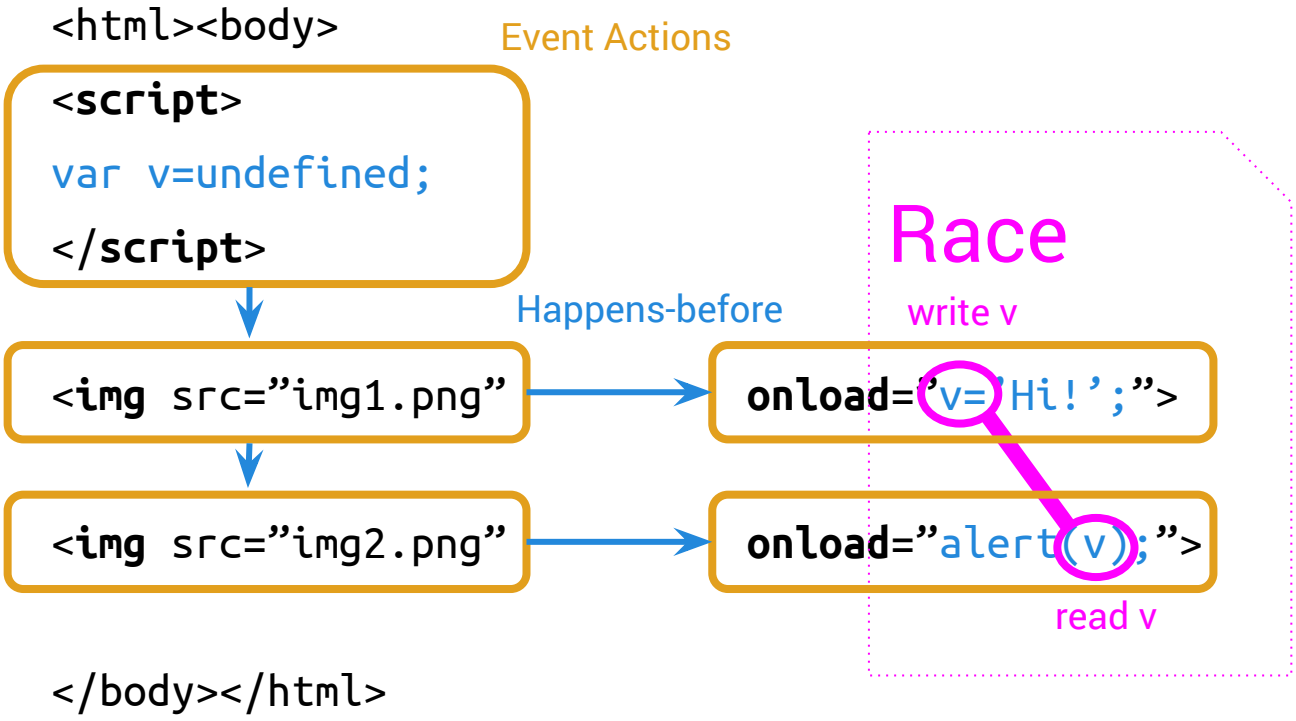
Understanding the problem



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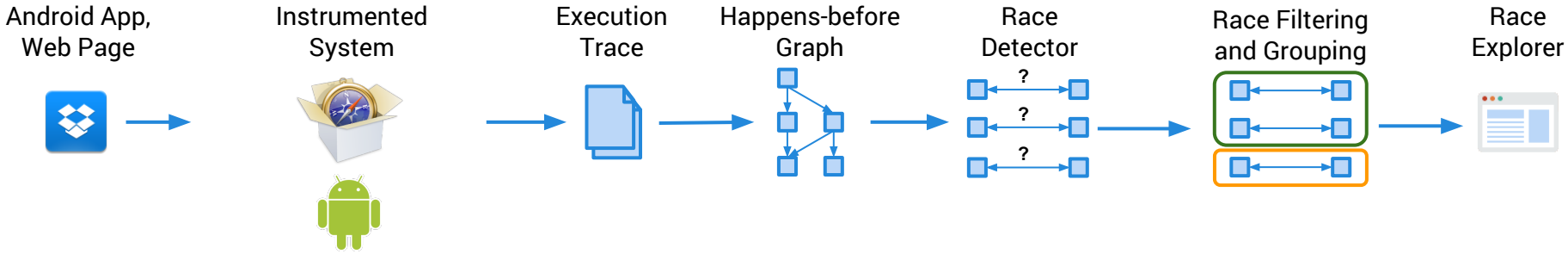
EventRacer end-to-end System



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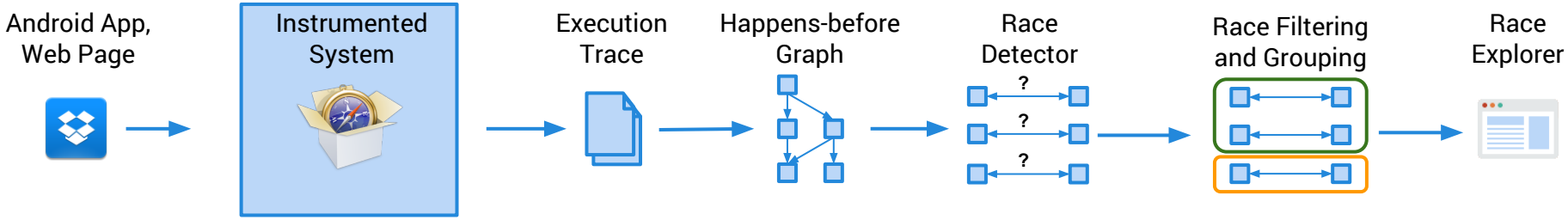

What are the memory locations on which asynchronous events can race?

JS variables, functions, arrays

```
<script>
v='Hi!';                    ↦ write(v)
function f() {}             ↦ write(f)
messages[2] = 42;           ↦ write(messages[2])
</script>
```

DOM nodes and attributes

```
<img id="img1" src="img1.png"        ↦ write(#img1)
     onload="v='Hi!';">              ↦ write(#img1.onload)

<script>
document.getElementById("img1")      ↦ read(#img1)
     .addEventListener("click", f);  ↦ write(#img1.click)
</script>
```


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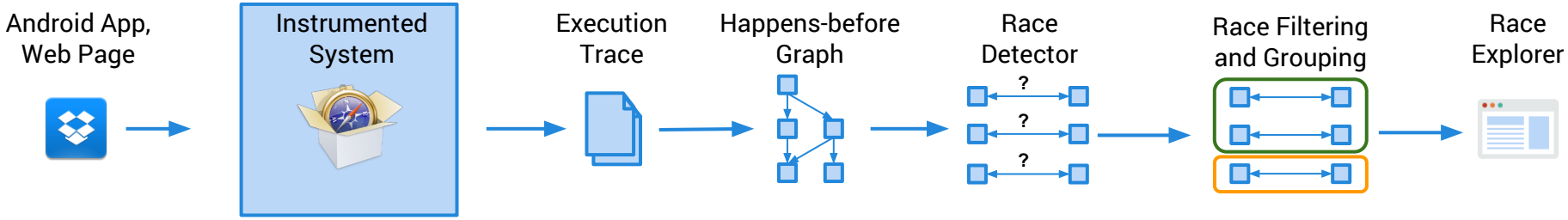
EventRacer end-to-end System



What are the atomic events used in event-driven applications?

Web
- parsing an HTML element
- executing a script
- handling user input
- ...

```
<script>
var v=undefined;
</script>
```

```
<img src="img1.png"
```

```
onload="v='Hi!';">
```

```
<img src="img2.png"
```

```
onload="alert(v);">
```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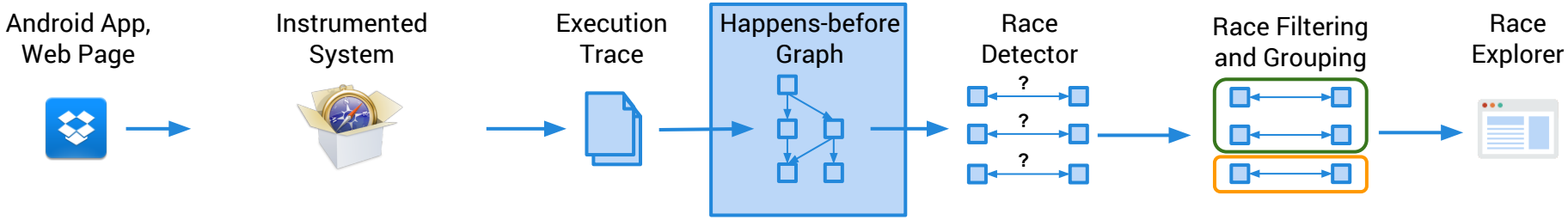
EventRacer end-to-end System



What is the event happens-before?

Web

`setInterval, SetTimeout, AJAX, …`

Android

`postDelayed, postAtFront, postIdle, ...`

```
<script>
var v=undefined;
</script>
```

Happens-before

```
<img src="img1.png"
```

```
onload="v='Hi!';">
```

```
<img src="img2.png"
```

```
onload="alert(v);">
```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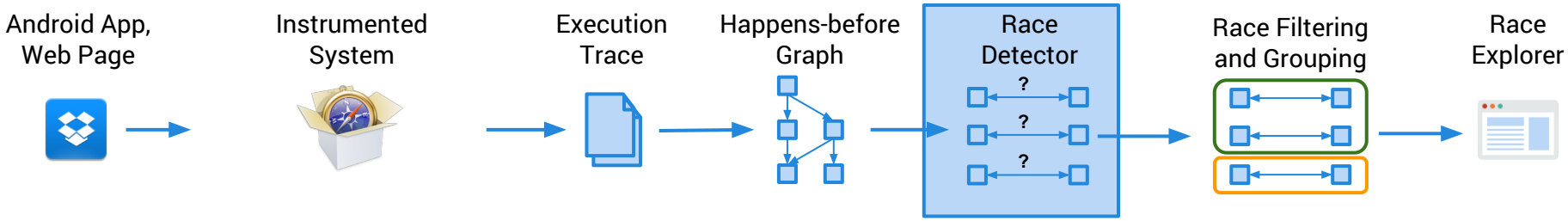
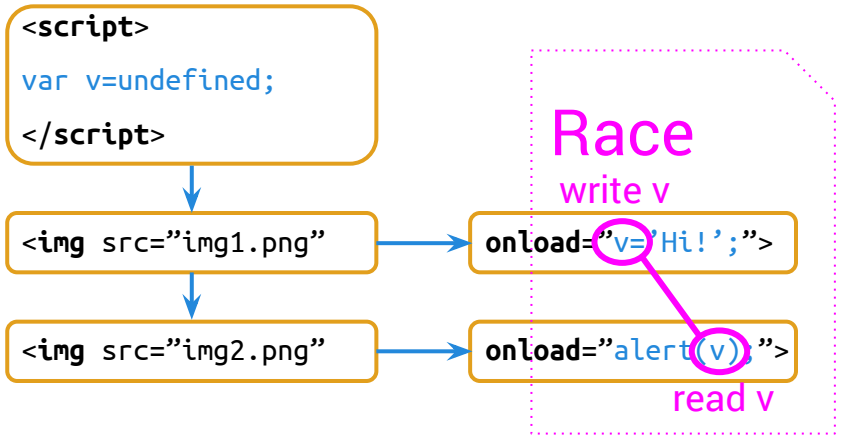
EventRacer end-to-end System



How to make scalable race detection in event-based setting?

(Naive algorithms have asymptotic complexity $O(N^3)$ and require $O(N^2)$ space)

	State of the art	EventRacer
runtime	TIMEOUT	2.4sec
memory	25181MB	171MB



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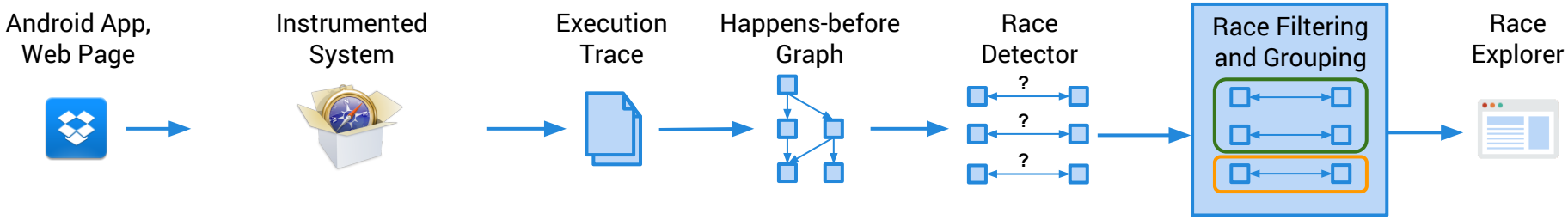
EventRacer end-to-end System



Is the system effective at finding harmful races while reporting few benign races?

We filter common classes of benign races:

commutative operations, recycled objects, lazy initialization, local reads, ...

	Web	Android
# races	646	1328
# reports	17.3	13
reduction	**37x**	**100x**

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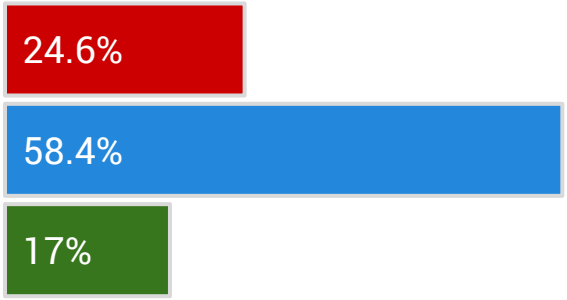
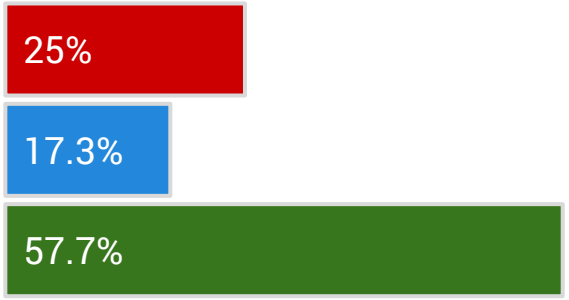
Manual evaluation

Web (314 reports)
Fortune 100 Web Pages



Android (104 reports)
8 Play Store Applications



Harmful bugs
- ✓ unhandled exceptions
- ✓ UI glitches
- ✓ broken analytics
- ✓ page needs refresh to work normally

synchronization races
various idioms:
- ✓ if (ready) …
- ✓ try { … } catch { retry }
- ✓ array of callbacks
- ✓ etc.

harmless races
- ✓ commutative operations
- ✓ benign races
- ✓ framework related

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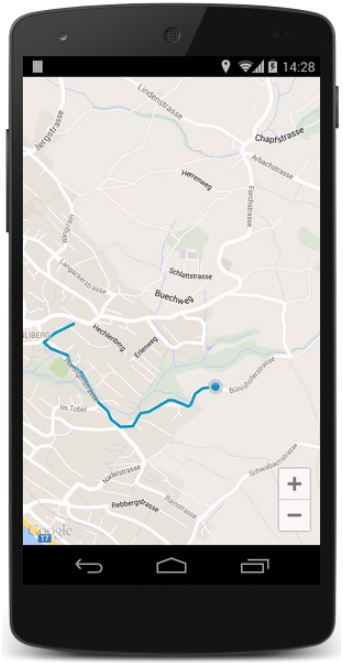
Simple GPS Tracker

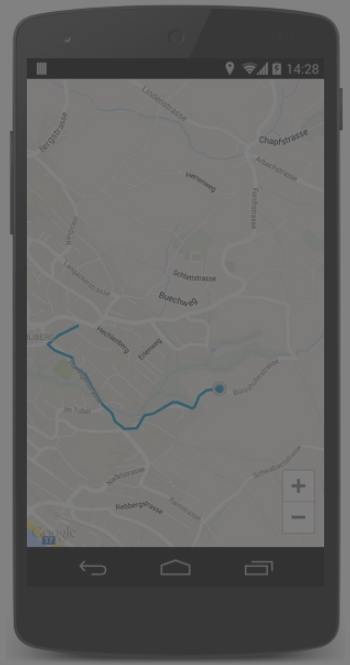



```
protected void onCreate() {
  locationManager.requestLocationUpdates(GPS_PROVIDER, 0, 0, mListener);
  mDbHelper = new SQLiteOpenHelper(this, DB_NAME, DB_VERSION);
}
```

```
LocationListener mListener = new LocationListener() {
  public void onLocationChanged(Location location) {
    //show location on map
    mDbHelper.getWritableDatabase().insert(loc);
  } };
```

```
protected void onStop() {
  locationManager.removeUpdates(mListener);
  mDbHelper.close();
}
```

Simple GPS Tracker



```
protected void onCreate() {
  locationManager.requestLocationUpdates(GPS_PROVIDER, 0, 0, mListener);
  mDbHelper = new SQLiteOpenHelper(this, DB_NAME, DB_VERSION);
}
```

```
LocationLis
  public vo
    //show
    mDbHelp
  } };
```

public void removeUpdates (LocationListener listener)

Added in API level 1

Removes all location updates for the specified LocationListener. Following this call, updates will no longer occur for this listener.

```
protected void onStop() {
  locationManager.removeUpdates(mListener);
  mDbHelper.close();
}
```

Is the Alternative Interleaving Feasible?

```
D/GPS: onCreate
D/GPS: insert: Location[gps 47.284646,8.632389 acc=10 et=0 vel=2.0 mock]
D/GPS: insert: Location[gps 47.284656,8.632598 acc=10 et=0 vel=2.0 mock]
D/GPS: insert: Location[gps 47.284712,8.632722 acc=10 et=0 vel=2.0 mock]
D/GPS: insert: Location[gps 47.284832,8.632837 acc=10 et=0 vel=2.0 mock]
D/GPS: onStop
D/GPS: insert: Location[gps 47.285022,8.633205 acc=10 et=0 vel=2.0 mock]

E/AndroidRuntime: FATAL EXCEPTION: main
E/AndroidRuntime: Process: com.example.gps, PID: 2249
E/AndroidRuntime: java.lang.IllegalStateException: attempt to re-open an
already-closed object: SQLiteDatabase: /data/data/com.example.gps/test.db
```

Current Directions

Google Chromium port

- V8 javascript engine instrumentation

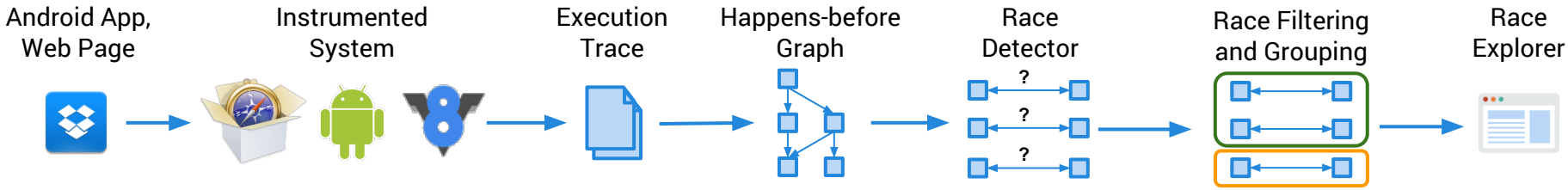
Testing tools based on EventRacer

- Integration with Selenium
- PhantomJS

Application for Parallelization

Other Application Domains (beyond Web Pages, Android)

- Node.js



www.eventracer.org

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