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Lecture 18

Profiling & Optimization

Sources of Game Performance Issues?

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Avoid Premature Optimization

- Novice developers rely on **ad hoc** optimization
  - Make private data public
  - Force function inlining
  - Decrease code modularity

  } removes function calls

- But this is a **very bad idea**
  - Rarely gives significant performance benefits
  - Non-modular code is very hard to maintain
- Write clean code first; optimize later

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Performance Tuning

- Code follows an 80/20 rule (or even 90/10)
  - 80% of run-time spent in 20% of the code
  - Optimizing other 80% provides little benefit
  - Do nothing until you know what this 20% is
- Be careful in **tuning performance**
  - Never overtune some inputs at expense of others
  - Always focus on the overall algorithm first
  - Think hard before making non-modular changes

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What Can We **Measure**?

Time Performance

- What code takes most time
- What is called most often
- How long I/O takes to finish
- Time to switch threads
- Time threads hold locks
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Memory Performance

- Number of heap allocations
- Location of allocations
- Timing of allocations
- Location of releases
- Timing of releases
- (Location of memory leaks)

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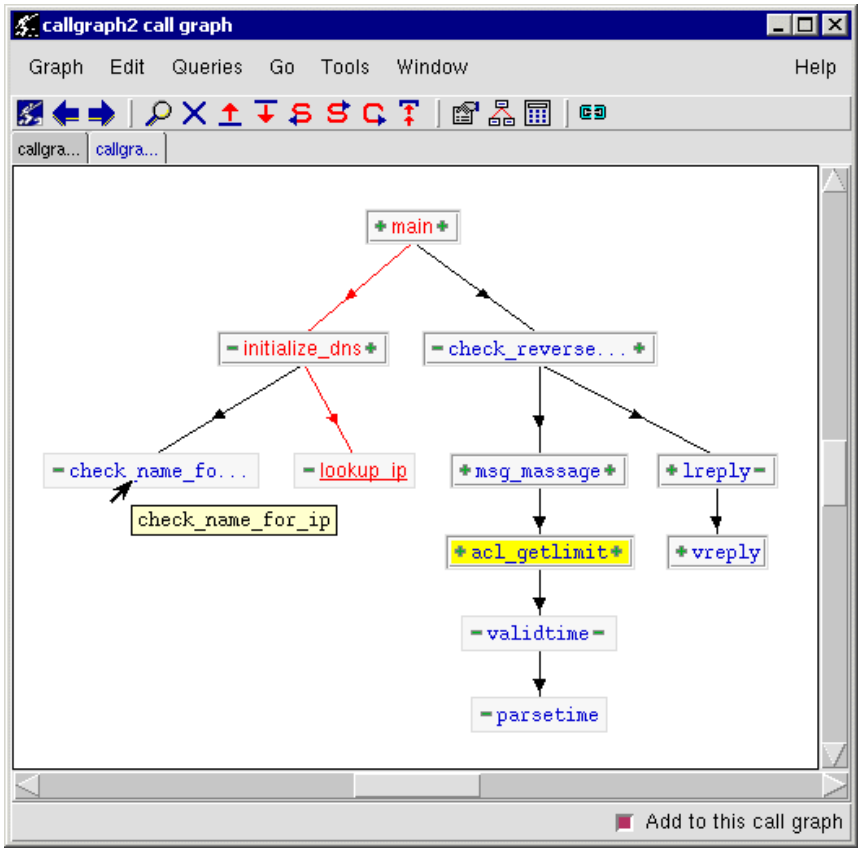
Analysis Methods

Static Analysis

- Analyze without running
  - Relies on language features
  - Major area of PL research
- **Advantages**
  - Offline; no performance hit
  - Can analyze deep properties
- **Disadvantages**
  - Conservative; misses a lot
  - Cannot capture user input



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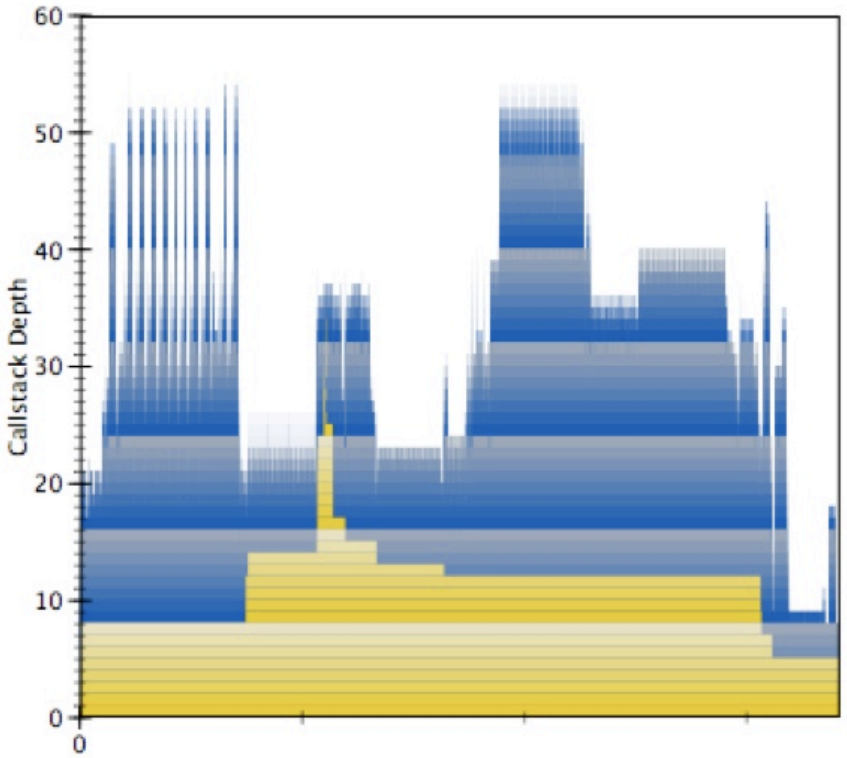
Analysis Methods



Profiling

- Analysis runs with program
  - Record behavior of program
  - Helps visualize this record
- **Advantages**
  - More data than static anal.
  - Can capture user input
- **Disadvantages**
  - Hurts performance a lot
  - May *alter* program behavior

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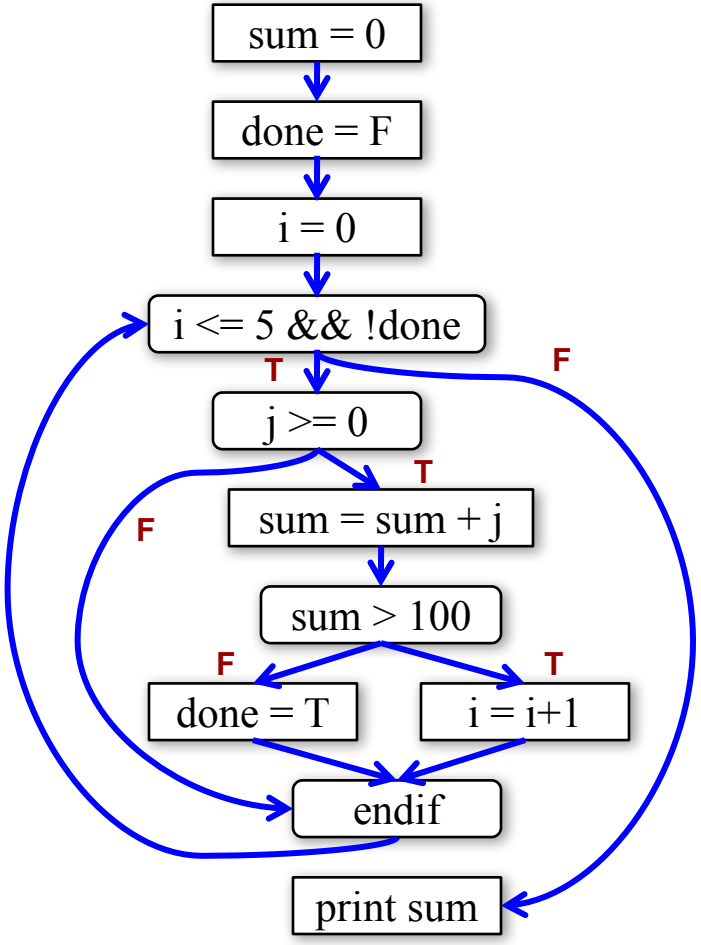
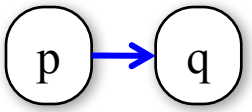
Static Analysis: Control Flow

```
int sum = 0
boolean done = false;
for(int ii; ii<=5 &&!done;) {
   if (j >= 0) {
      sum += j;
      if (sum > 100) {
         done = true;
      } else {
         i = i+1;
      }
}}
print(sum);
```





q may be executed immediately after p

Static Analysis: Flow Dependence

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boolean done = false;
for(int ii; ii<=5 &&!done;) {
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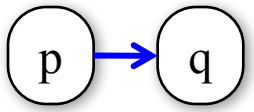
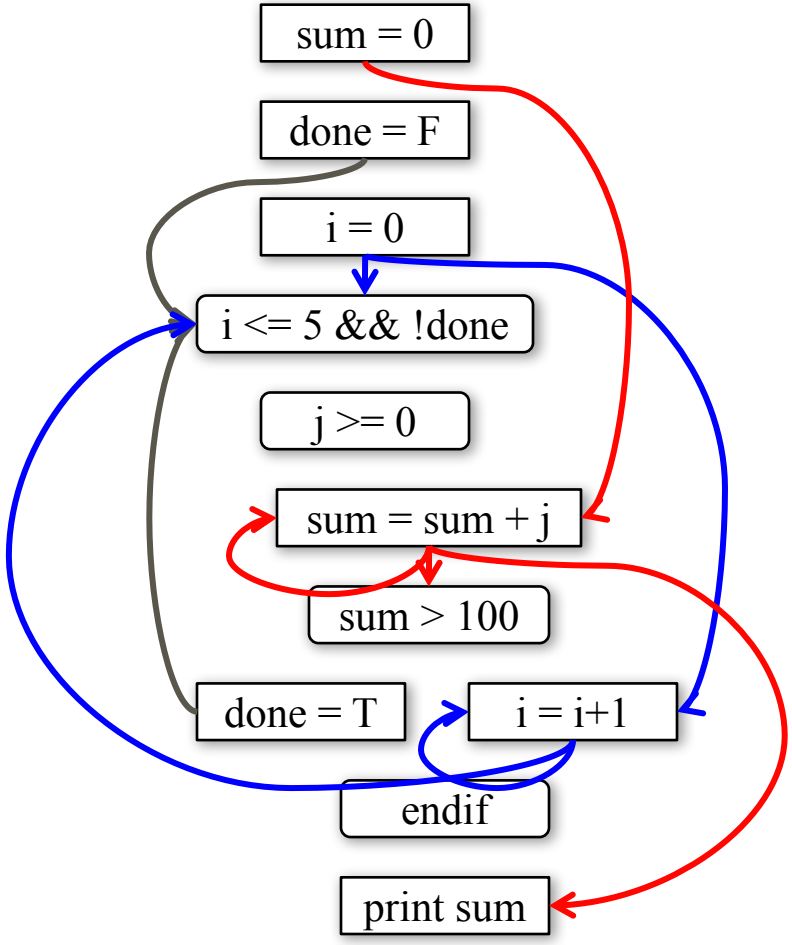
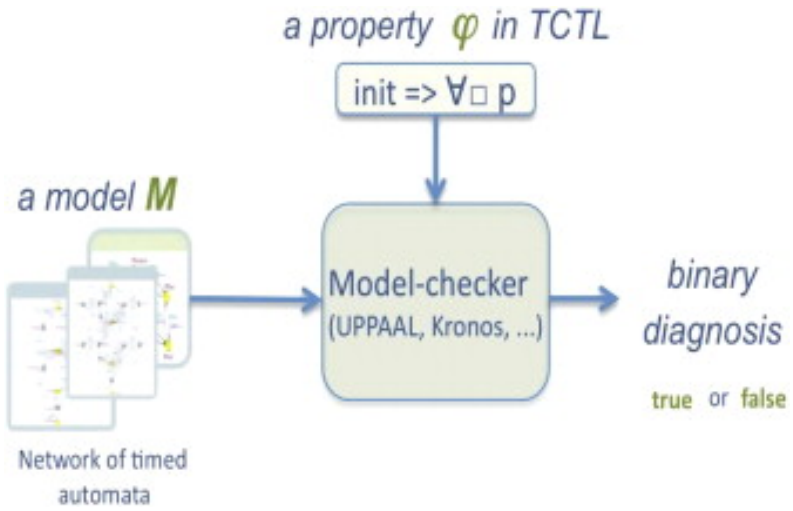
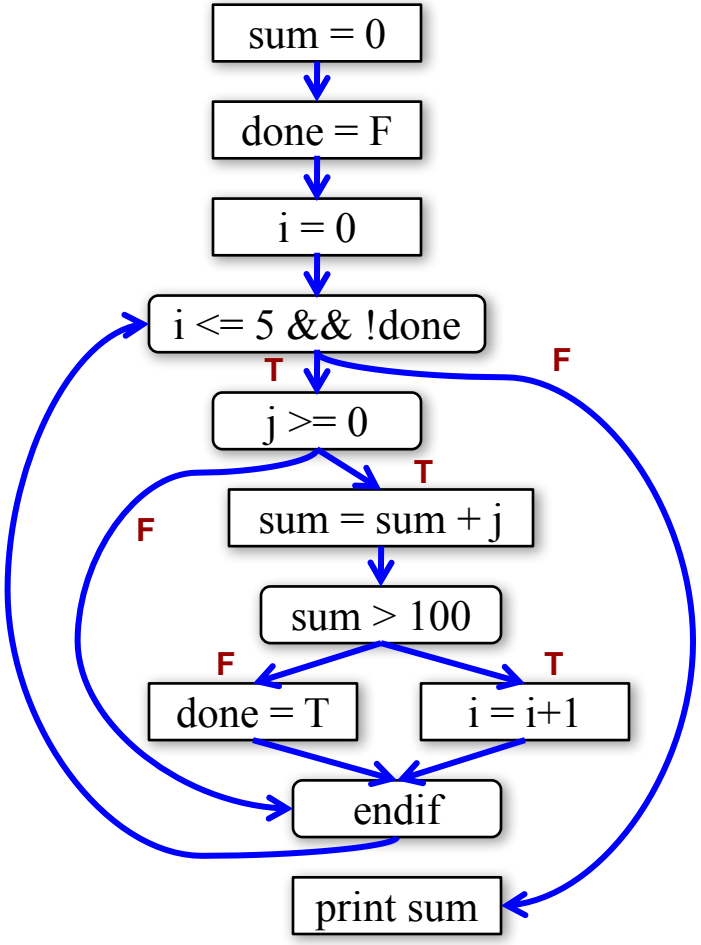


Value assigned at p
is read at command q



Model Checking





- Given a graph, logical formula φ
  - φ expresses properties of graph
  - Checker determines if is true
- Often applied to software
  - Program as control-flow graph
  - φ indicates acceptable paths

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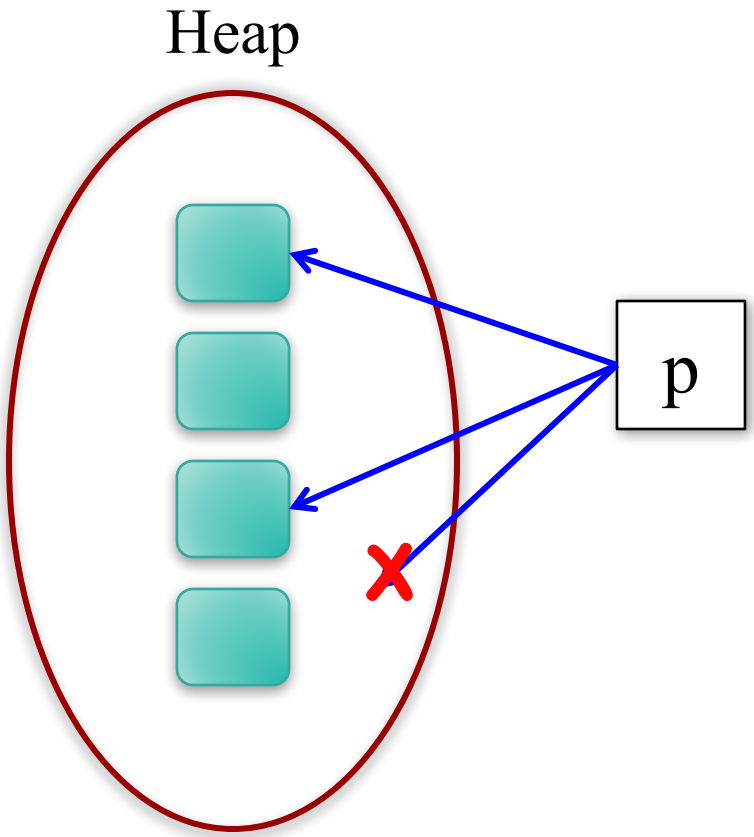
Static Analysis: Applications

- **Pointer analysis**
  - Look at pointer variables
  - Determine possible values for variable at each place
  - Can find memory leaks
- **Deadlock detection**
  - Locks are flow dependency
  - Determine possible owners of lock at each position
- **Dead code analysis**



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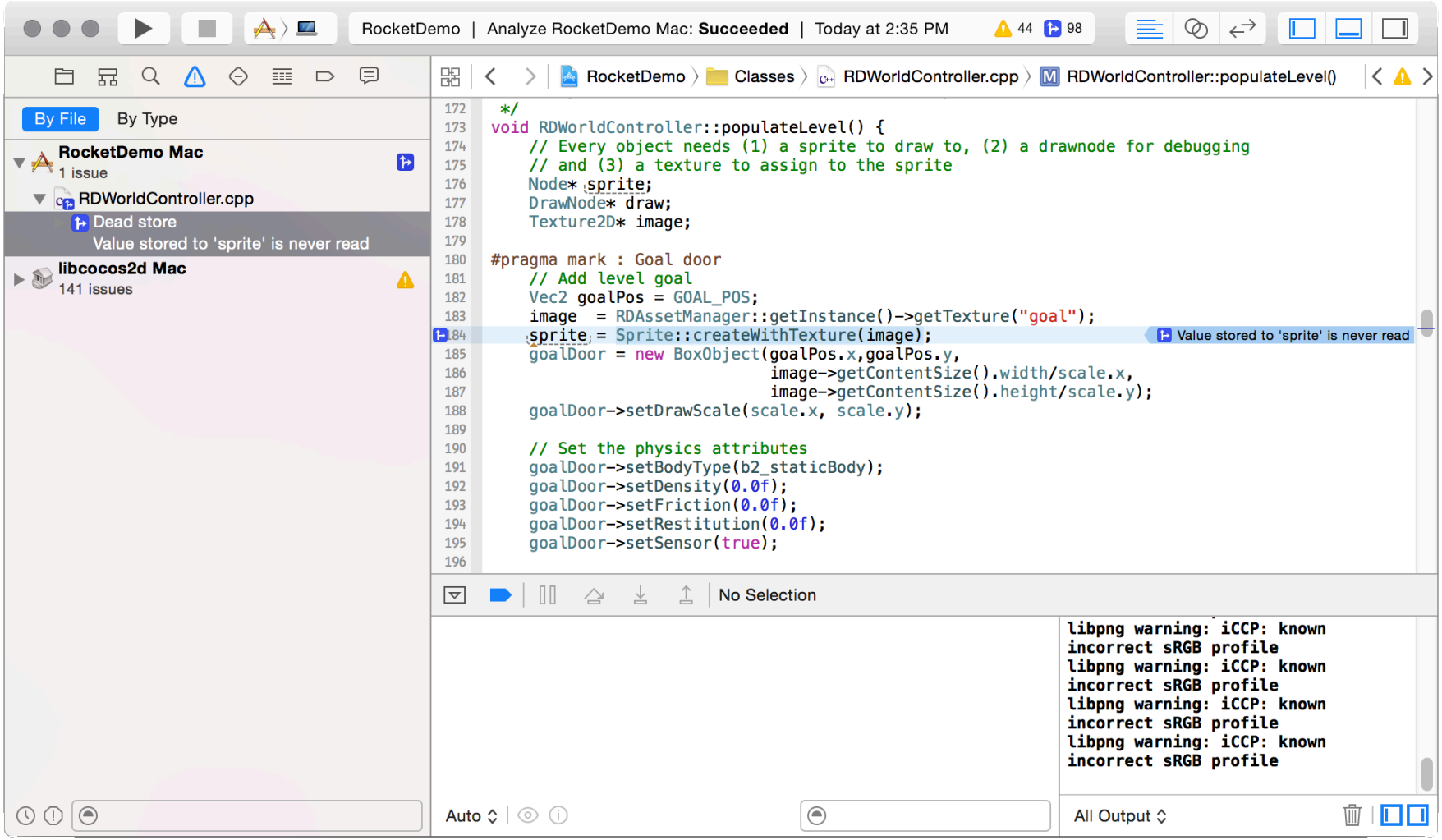
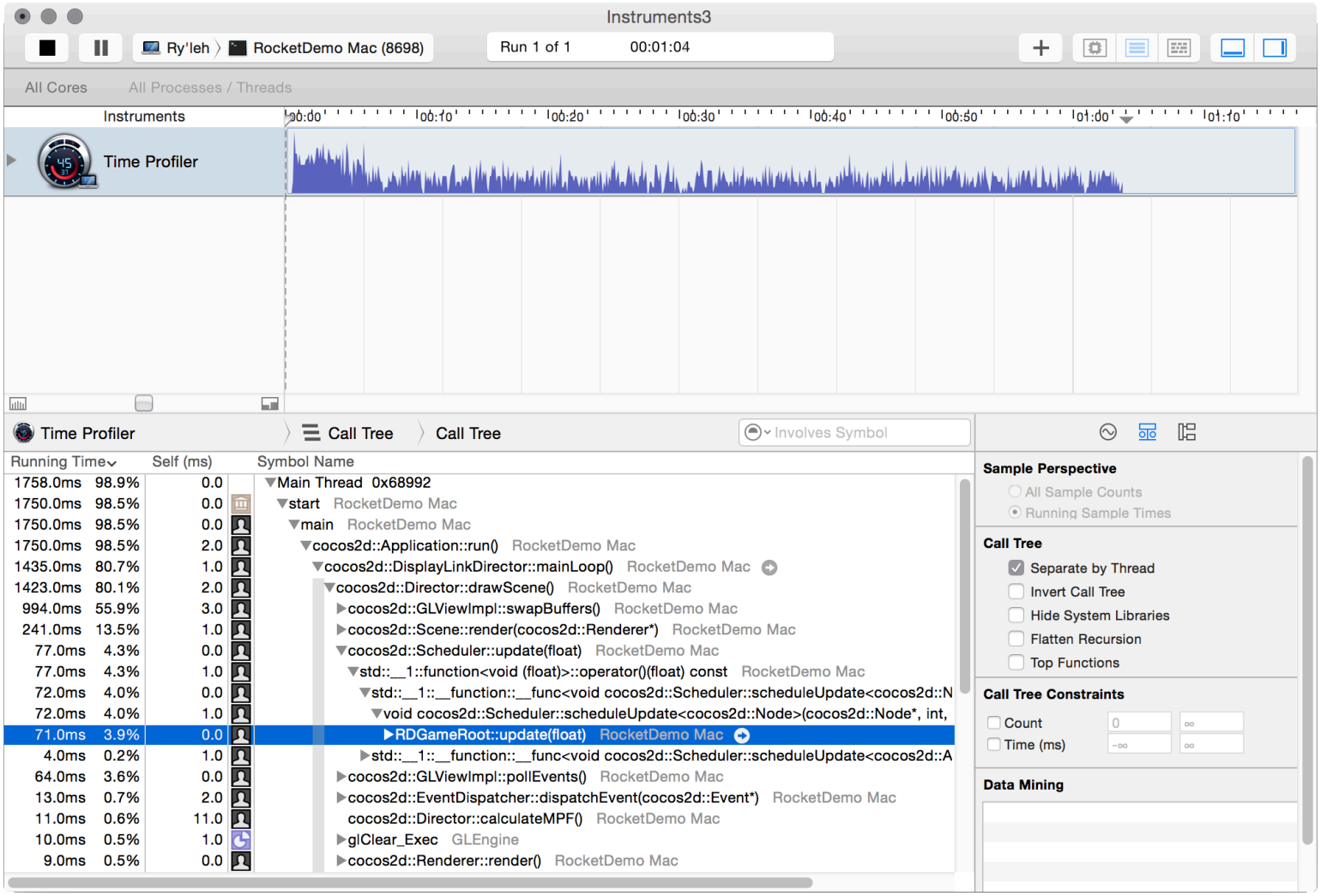
Example: Analyze in X-Code



Time Profiling



Time Profiling: Methods

Software

- Code added to program
  - Captures start of function
  - Captures end of function
  - Subtract to get time spent
  - Calculate percentage at end
- **Not completely accurate**
  - Changes actual program
  - Also, how get the time?

Hardware

- Measurements in hardware
  - Feature attached to CPU
  - Does not change how the program is run
- Simulate w/ hypervisors
  - Virtual machine for Oss
  - VM includes profiling measurement features
  - **Example**: Xen Hypervisor

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Time Profiling: Methods

Time-Sampling

- Count at periodic intervals
  - Wakes up from sleep
  - Looks at parent function
  - Adds that to the count
- Relatively lower overhead
  - Doesn't count everything
  - Performance hit acceptable
- May miss small functions

Instrumentation

- Count pre-specified places
  - Specific function calls
  - Hardware interrupts
- Different from sampling
  - Still not getting everything
  - But **exact view** of slice
- Used for targeted searches

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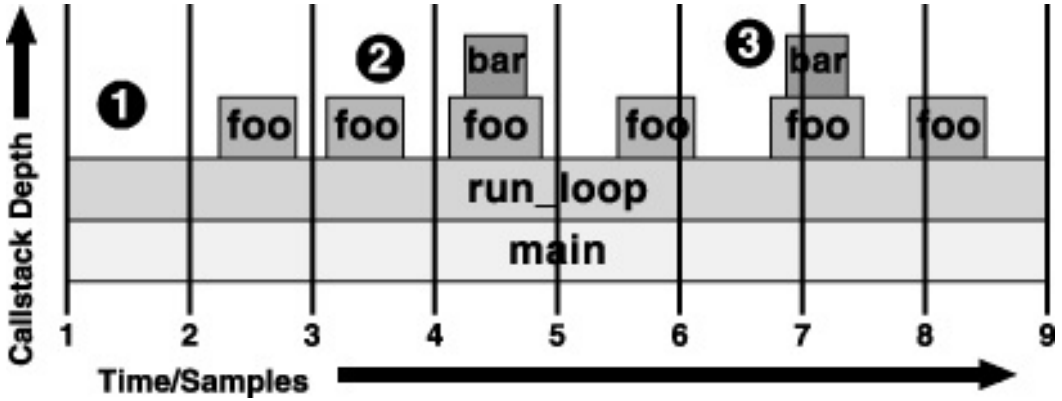
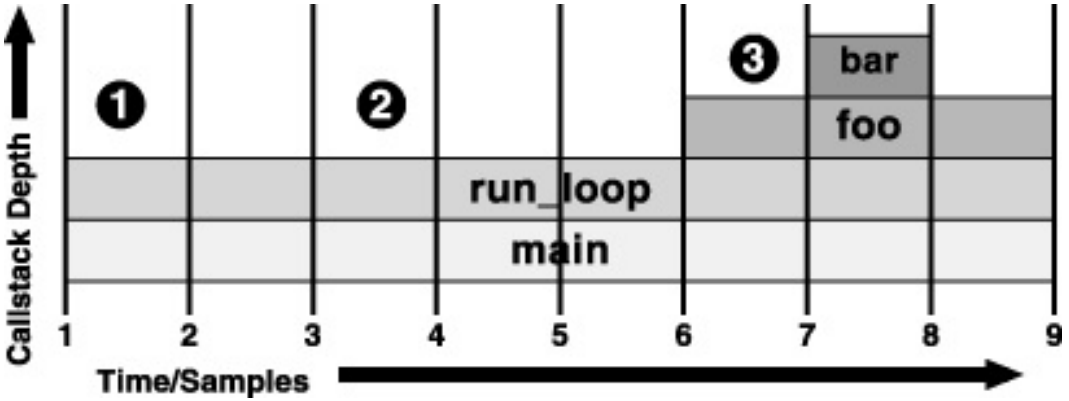
Issues with Periodic Sampling

Real



Sampled



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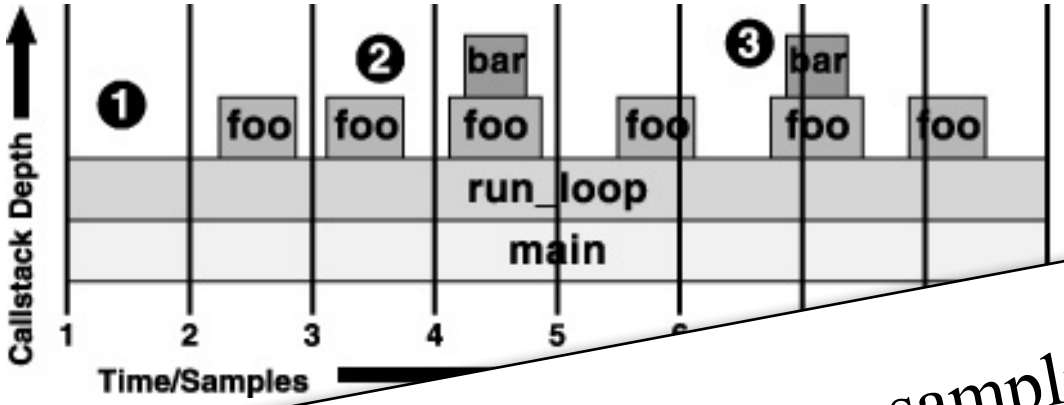

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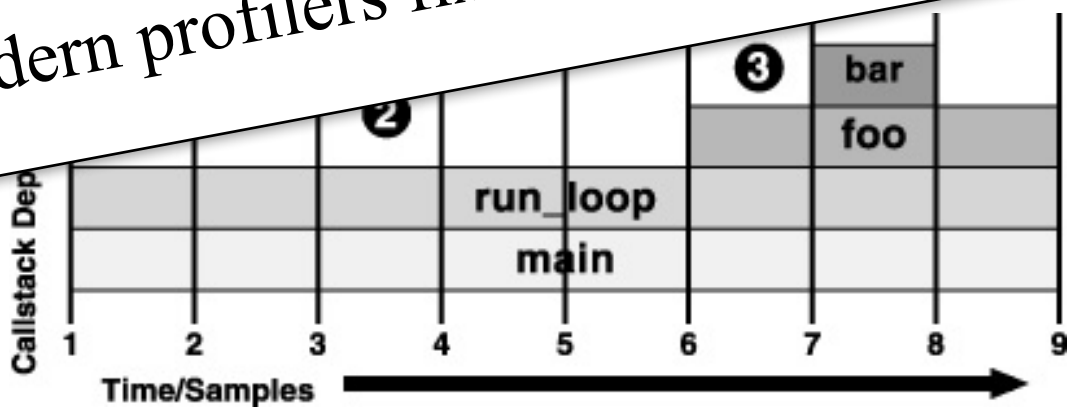

Modern profilers fix with random sampling

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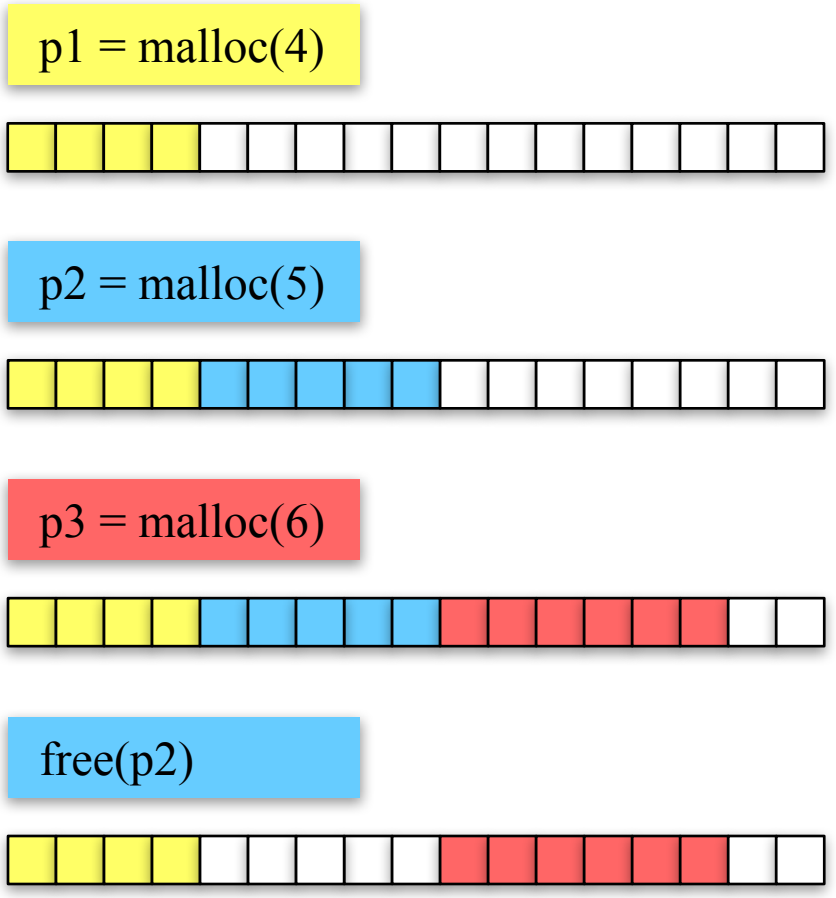
Instrumentation: Memory

- Memory handled by malloc
  - Basic C allocation method
  - C++ `new` uses malloc
  - Allocates raw bytes
- malloc can be **instrumented**
  - Count number of mallocs
  - Track malloc addresses
  - Look for frees later on
- Finds memory leaks!



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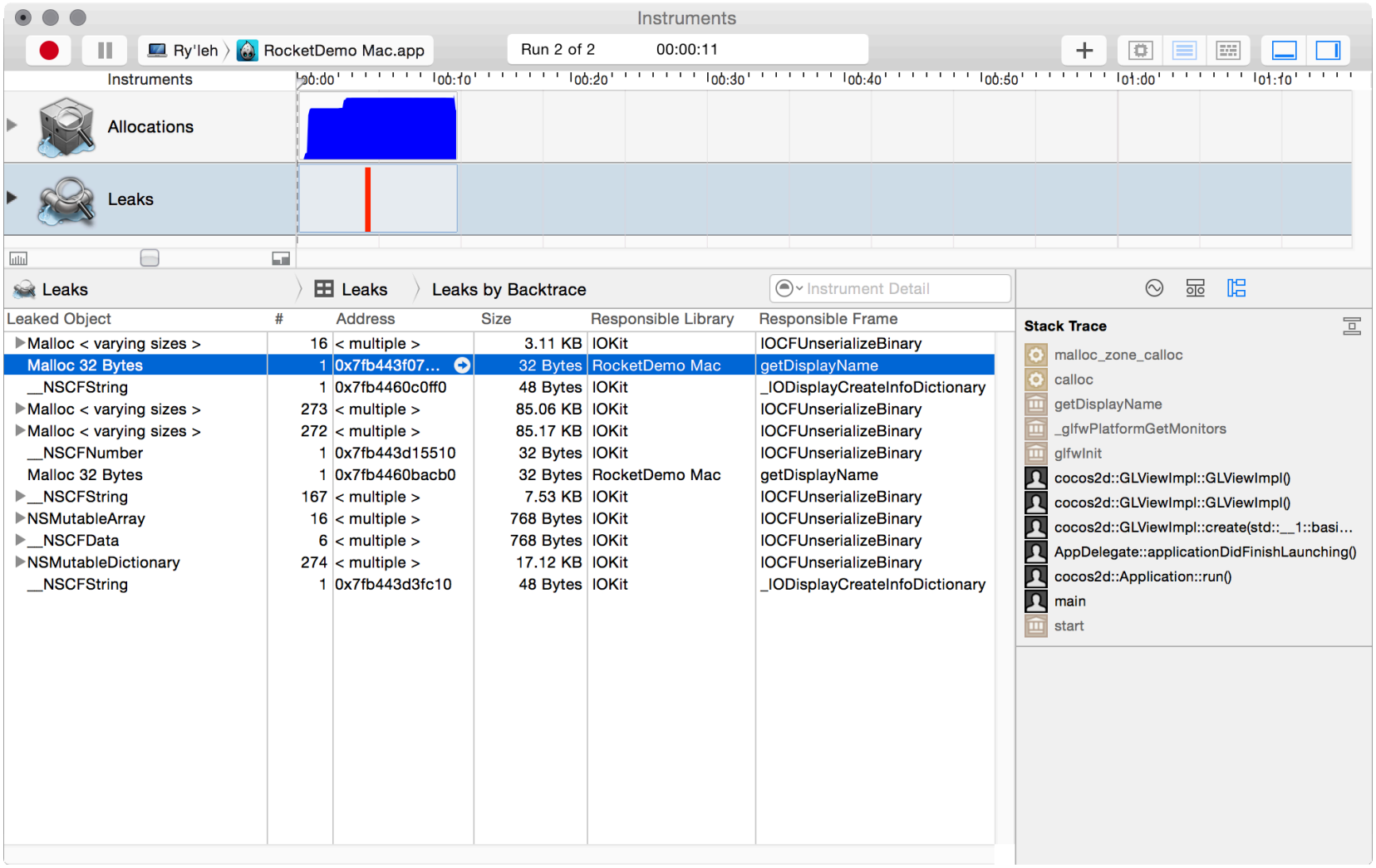
Instrumentation: Memory



Profiling Tools

- **iOS/X-Code**
  - Instruments (wide variety of special tools)
  - GNU gprof (Profile ⌘I) for sampled time
- **Android (Java)**
  - Dalvik Debug Monitor Server (DDMS) for traces
  - TraceView helps visualize the results of DDMS
- **Android (C++)**
  - Android NDK Profiler (3rd party)
  - GNU gprof visualizes the results of `gmon.out`

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Android NDK Profiling

```
// Non-profiled code
monstartup("your_lib.so");
// Profiled code
moncleanup();
// Non-profiled code
```

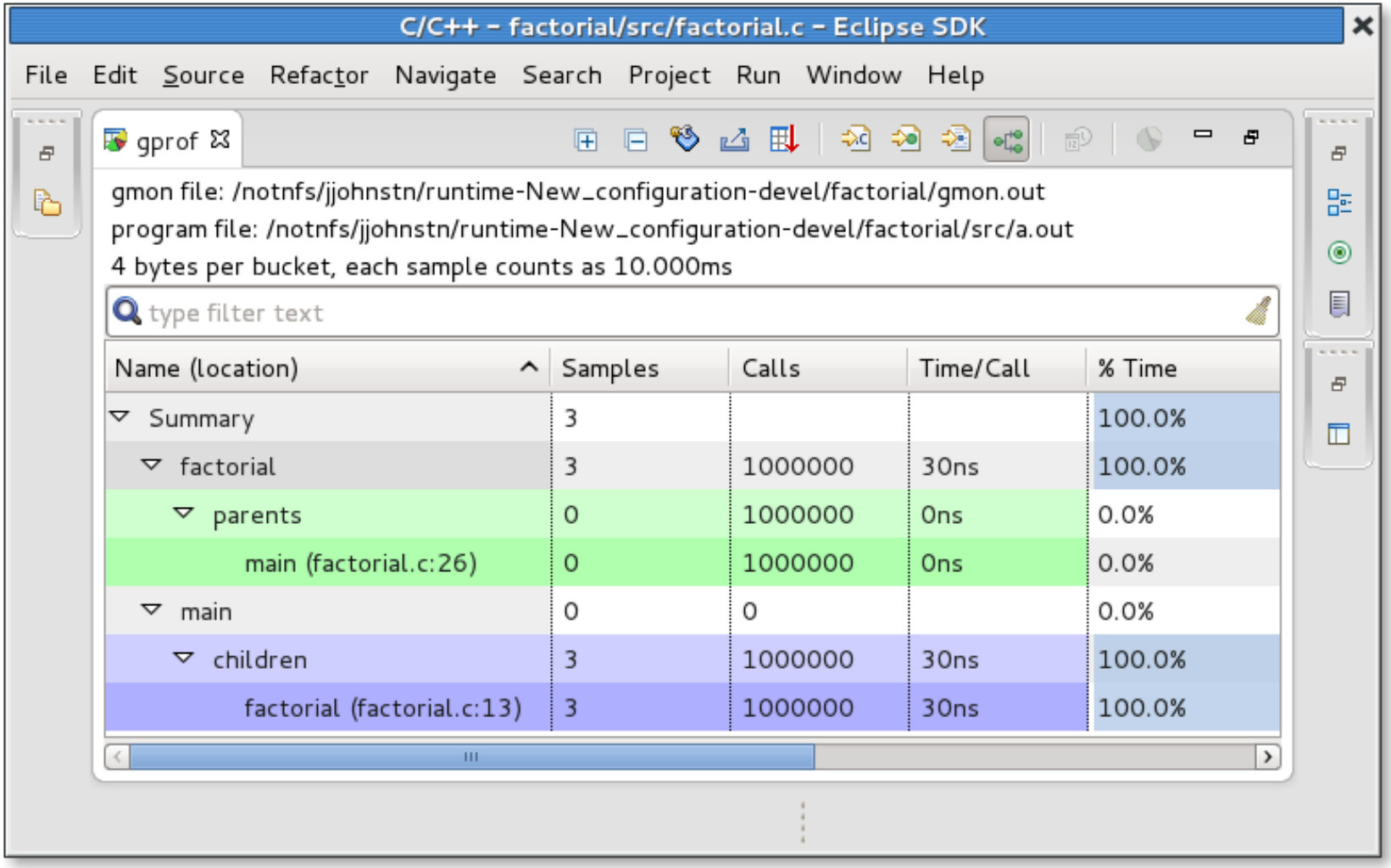
captures everything

Android App

gmon.out

gprof

Android Profiling



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Poor Man's Sampling

Call Graph

- Create a hashtable
  - Keys = pairs (*a* calls *b*)
  - Values = time (time spent)
- Place code around call
  - Code inside outer func. *a*
  - Code before & after call *b*
  - Records start and end time
  - Put difference in hashtable

Timing

- Use the processor's timer
  - Track time used by program
  - System dependent function
  - **Java**: `System.nanoTime()`
- Do not use "wall clock"
  - Timer for the whole system
  - Includes other programs
  - **Java** version: `System.currentTimeMillis()`

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call *b*

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  - by program
  - function
  - Time()
  - "wall clock"
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Useful in networked setting

Summary

- Premature optimization is bad
  - Make code unmanageable for little gain
  - Best to identify the bottlenecks first
- Static analysis is useful in some cases
  - Finding memory leaks and other issues
  - Deadlock and resource analysis
- Profiling can find runtime performance issues
  - But changes the program and incurs overhead
  - Sampling and instrumentation reduce overhead

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