University of Glasgow

The Judgment of Forseti

Economic Utility for Dynamic Heap Sizing of Multiple Runtimes

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digested talk

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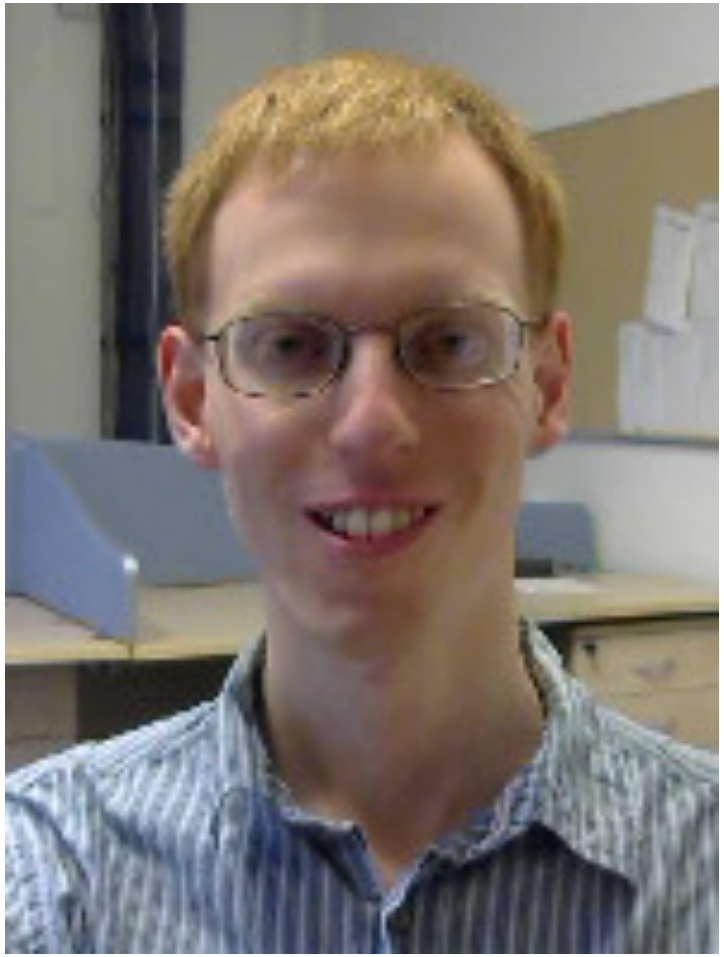
#forseti optimizes whole-system thruput by tweaking heap sizes of all executing JVMs simultaneously dx.doi.org/10.1145/275416… #ismm2015

David.Vengerov @ oracle.com

Callum.Cameron @ glasgow.ac.uk



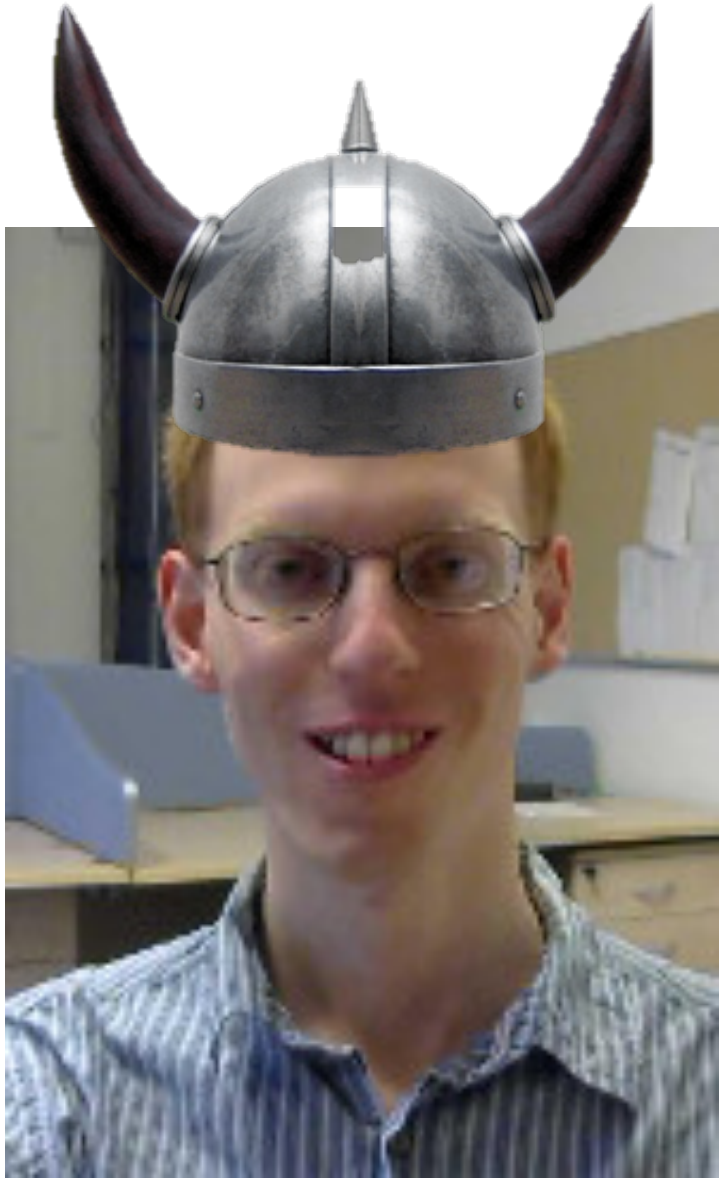



image: wikipedia.org

Motivation

dynamic memory resource allocation in *datacenters*


image: wikipedia.org

dynamic memory resource allocation in *smartphones*

image: wikipedia.org

Requirements

- Satisfy users
- Be economical

Characteristics of VM tasks

- elastic memory usage
- phased behavior

Automatic Mem Mgt

- a.k.a. *Garbage Collection (GC)*
- Automatically deallocate a block of memory when it is no longer reachable
- *Runtime Heap* grows/shrinks on a demand basis

Key Heap Metrics

- *Live size* – current amount of *live* data
- *Current heap occupancy* – current amount of *allocated* data (live and dead)
- *Heap limit* – max permitted value for current heap occupancy

What is the
optimal
heap limit?

Lots of possibilities

How do you find the best settings for your system? … for your application?

1. domain expertise
2. exhaustive search
3. mathematical model

State-of-the-art: Domain Expertise

```
Java -Xmx12g -XX:MaxPermSize=64M -XX:PermSize=32M-XX:MaxNewSize=2g
       -XX:NewSize=1g -XX:SurvivorRatio=128 -XX:+UseParNewGC
       -XX:+UseConcMarkSweepGC -XX:MaxTenuringThreshold=0
       -XX:CMSInitiatingOccupancyFraction=60 -XX:+CMSParallelRemarkEnabled
       -XX:+UseCMSInitatingOccupancyOnly -XX:ParallelGCThreads=12
       -XX:LargePageSizeInBytes=256m ...
```

slide: azulsystems.com

State-of-the-art: Exhaustive Search

The Taming of the Shrew: Increasing Performance by Automatic Parameter Tuning for Java Garbage Collectors

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ABSTRACT

Garbage collection, if not tuned properly, can considerably impact application performance. Unfortunately, configur-

However, while object allocations produce a direct and easy to understand performance impact, the costs of garbage collections are easily overlooked. Programmers are often un-

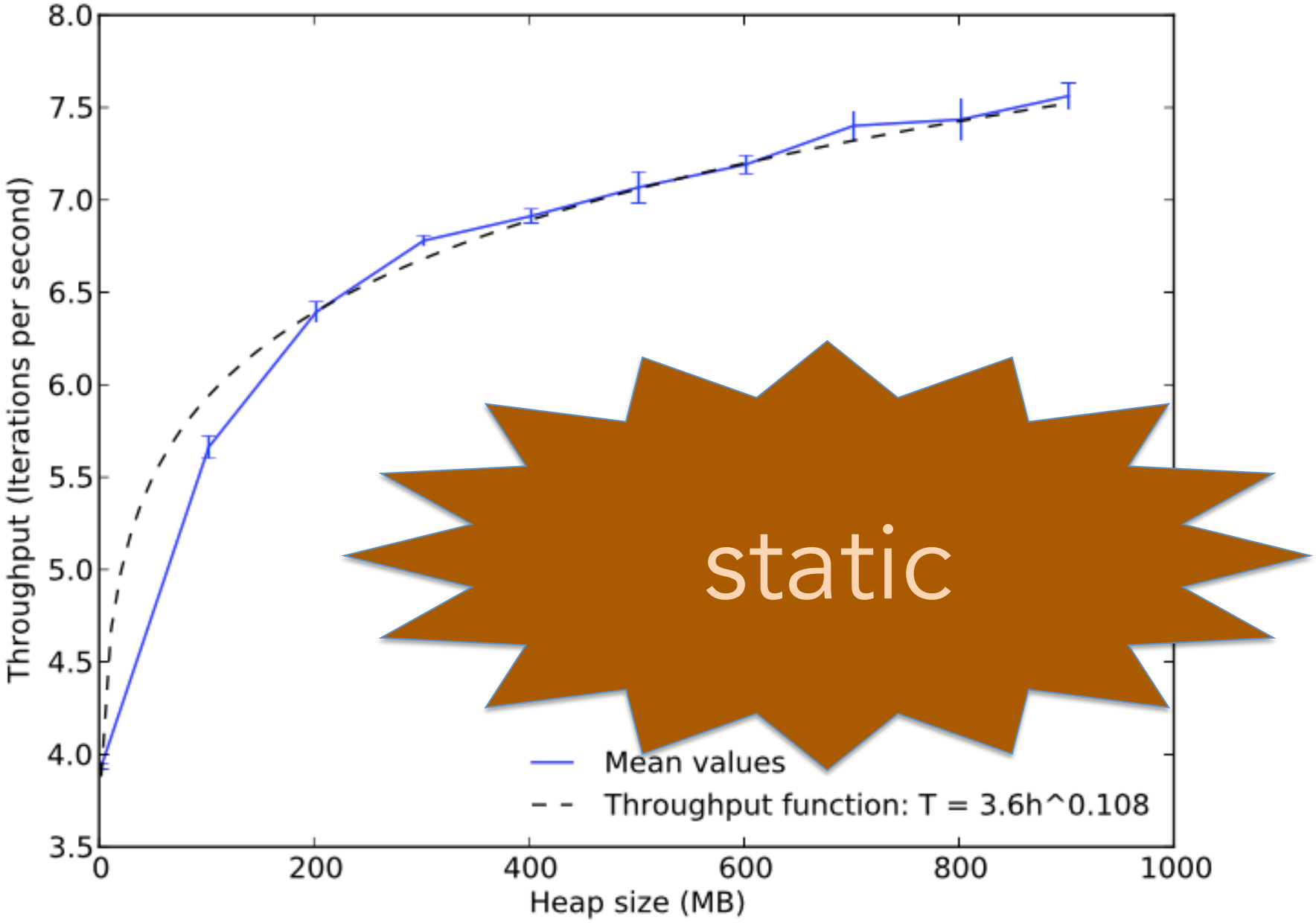
- around 300 GC parameters
- search parameter space for 4 hours
- select *best* configuration

[ICPE 2014]

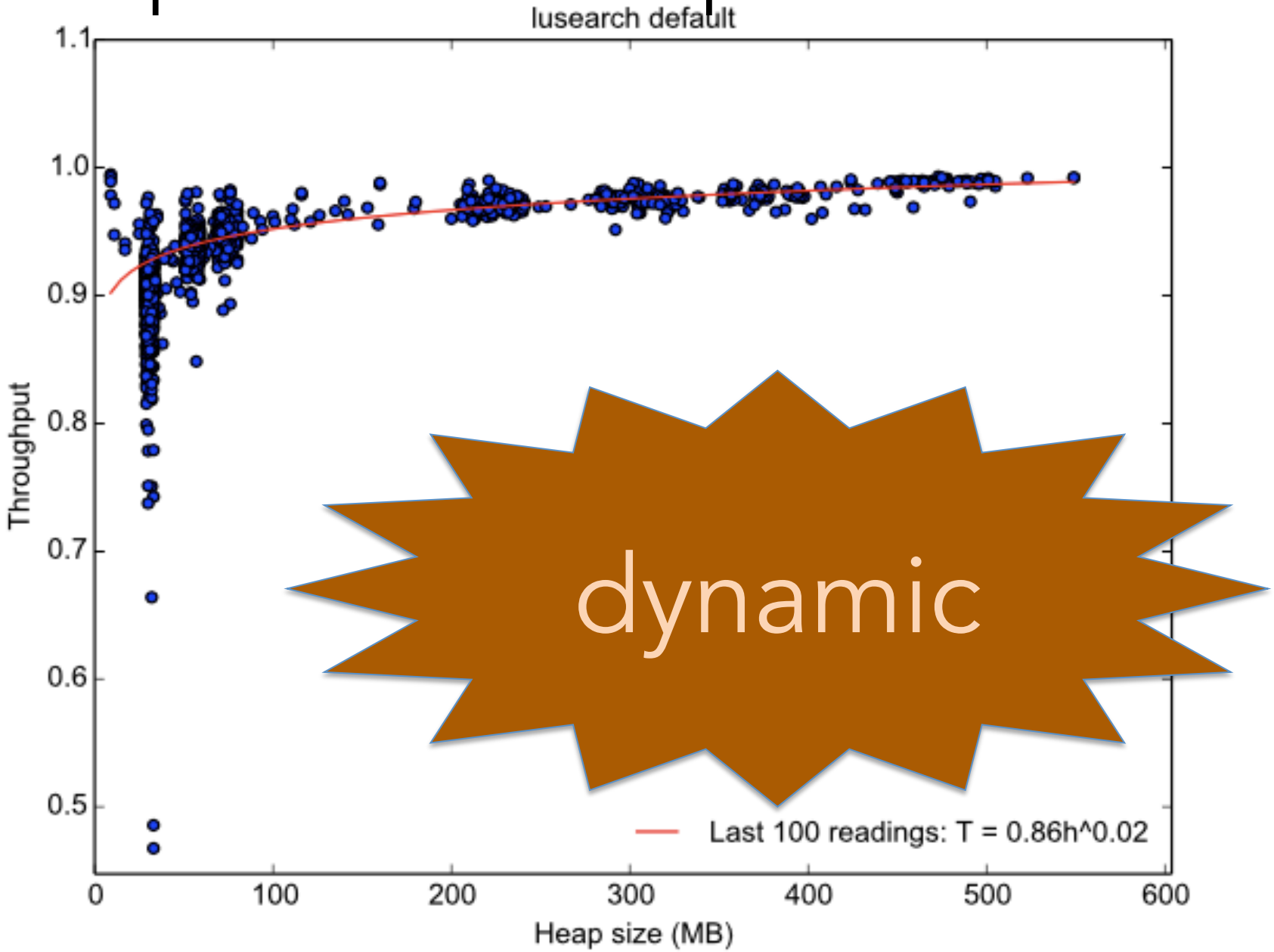
State-of-the-art: Mathematical Model

- decision tree
  - machine learning [ISMM 2007]
- supply/demand curve
  - economics [ISMM 2010]
- differential equations
  - control theory [ISMM 2013]

heap limit affects performance



heap limit affects performance



Math Model based on *economic utility*

For a single VM:

the utility function has form

$$U(h) = a h^{b}$$

with $a>0,\ 0 < b < 1$

Math Model based on *economic utility*

overall utility function for whole-system:

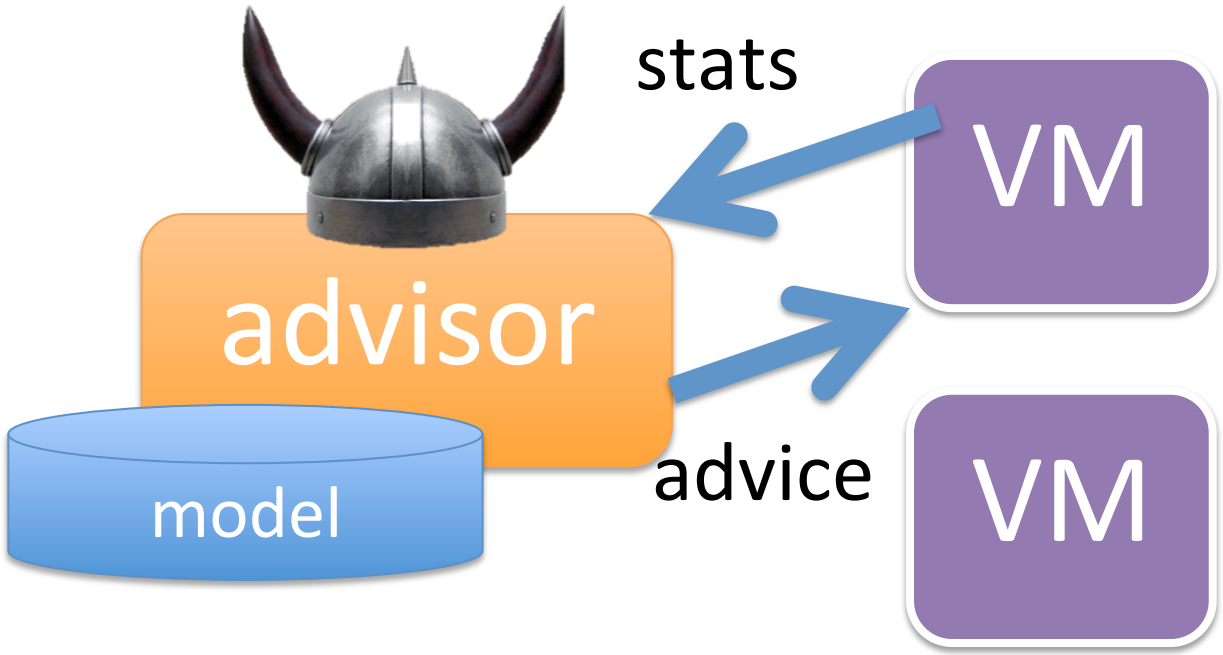
product of individual utilities

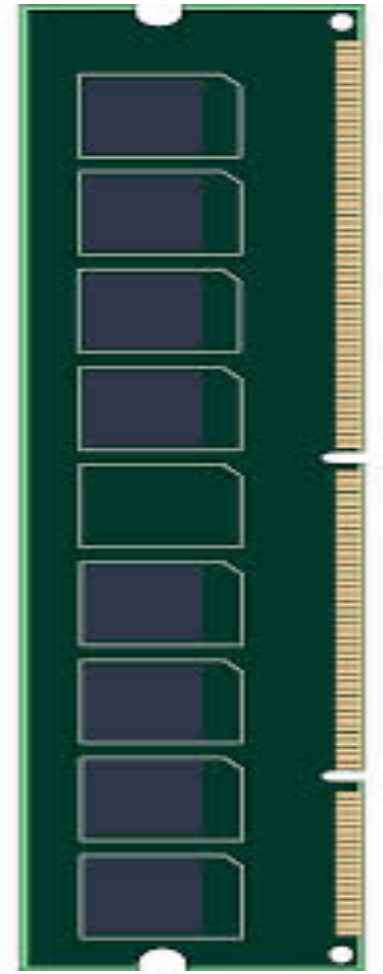
$$U(h_1, \ldots, h_n) = \prod_i a_i h_i^{b_i}$$

Math Model based on *economic utility*

- *maximise* overall utility function
  - possibly via analytic solution [ICOOOLPS'14]
  - here we use *numeric* optimization

Forseti concept

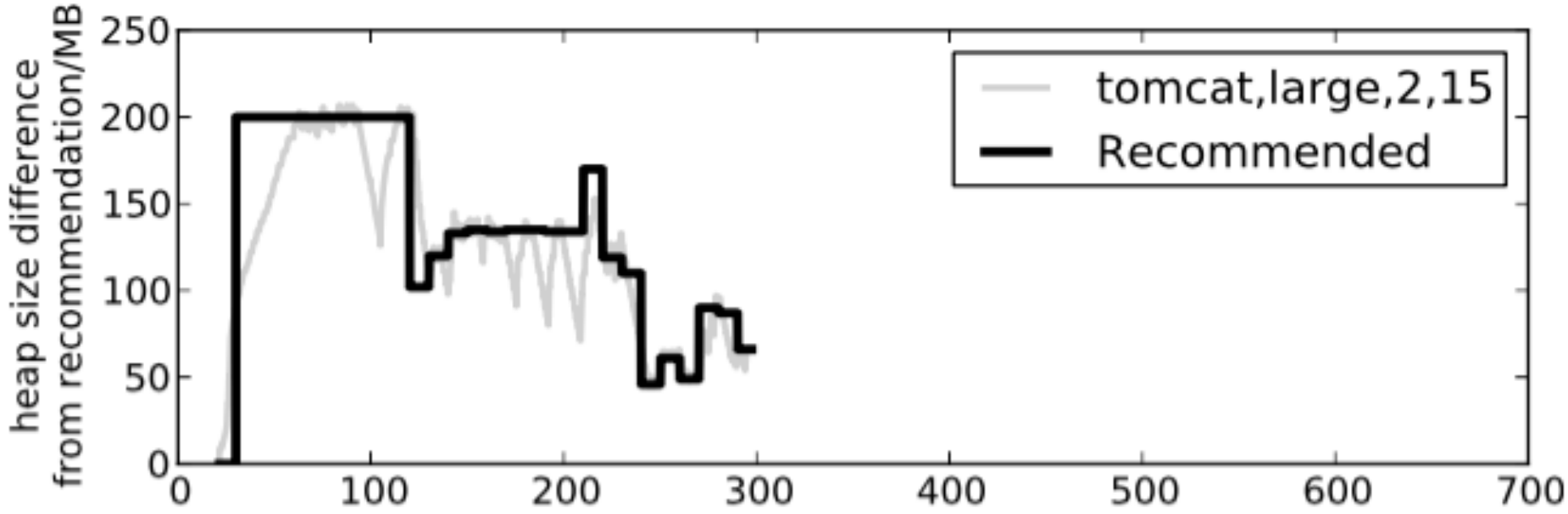


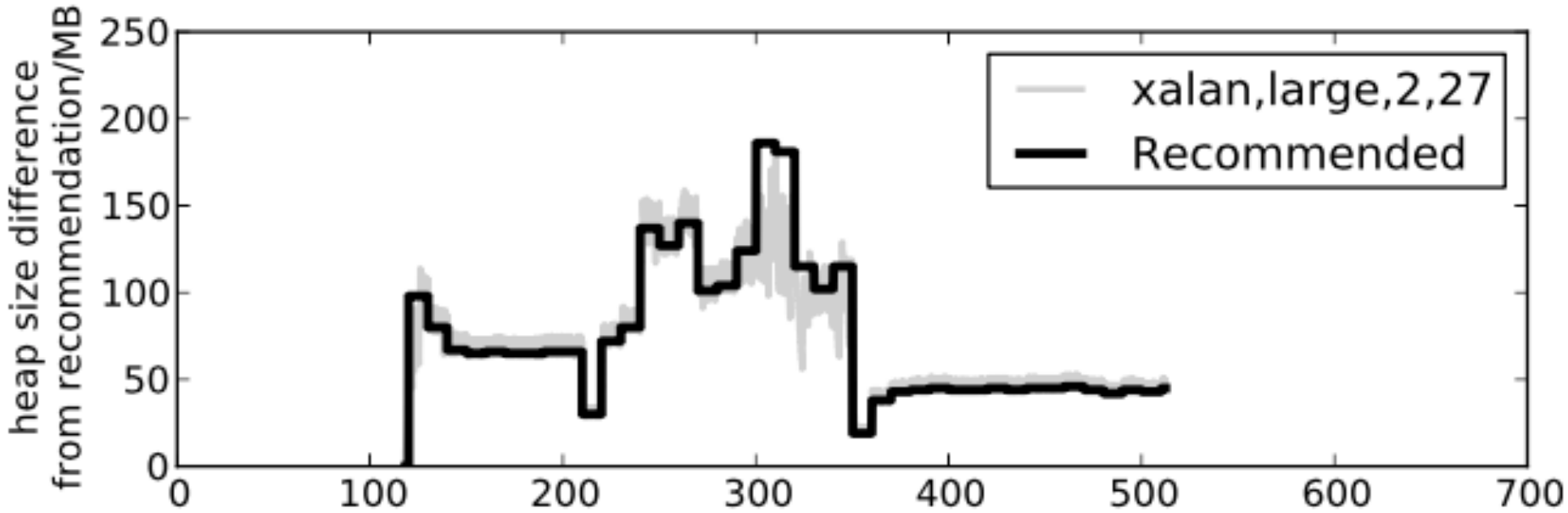


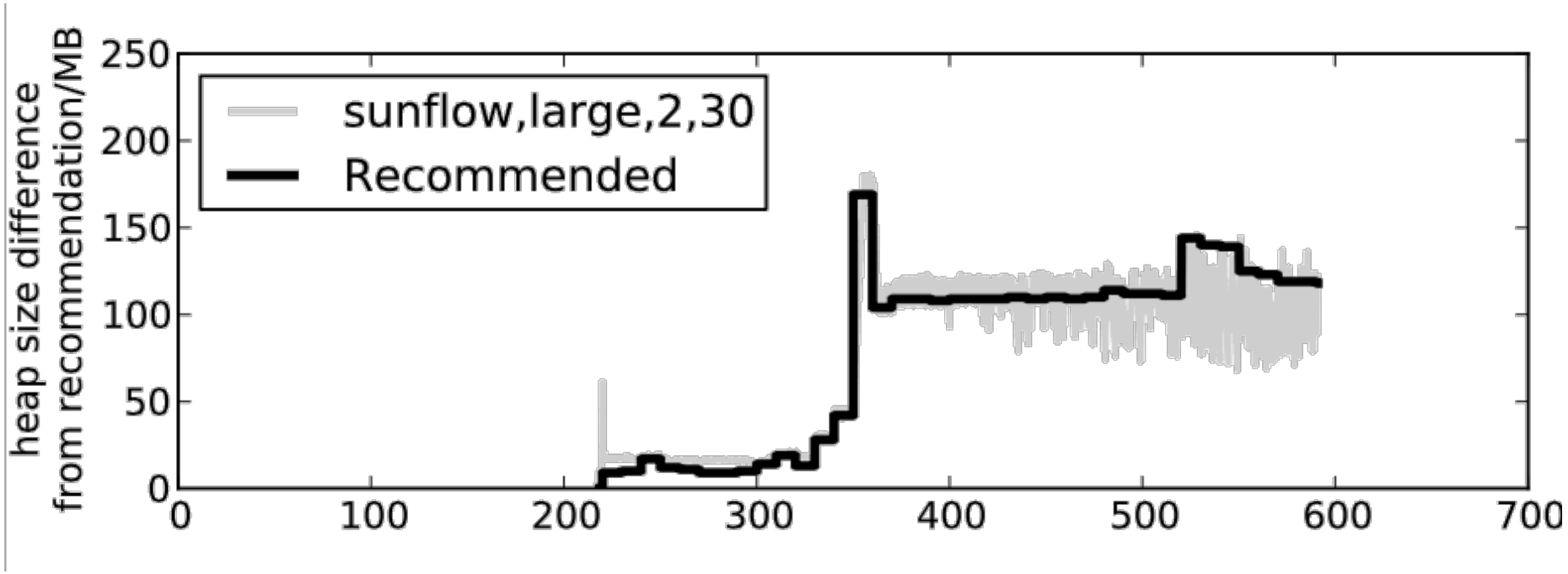
Evaluation

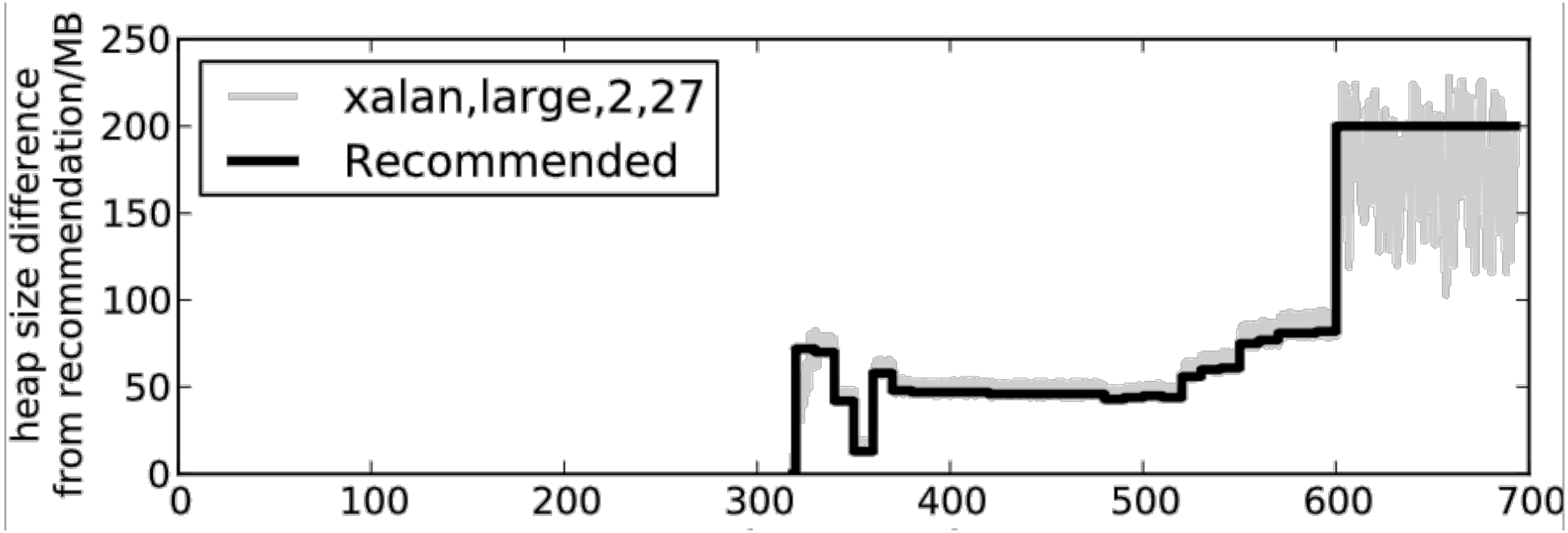
Experiment 1:

- run *4* DaCapo benchmarks
- staggered start times
- set target total mem usage to *200MB*

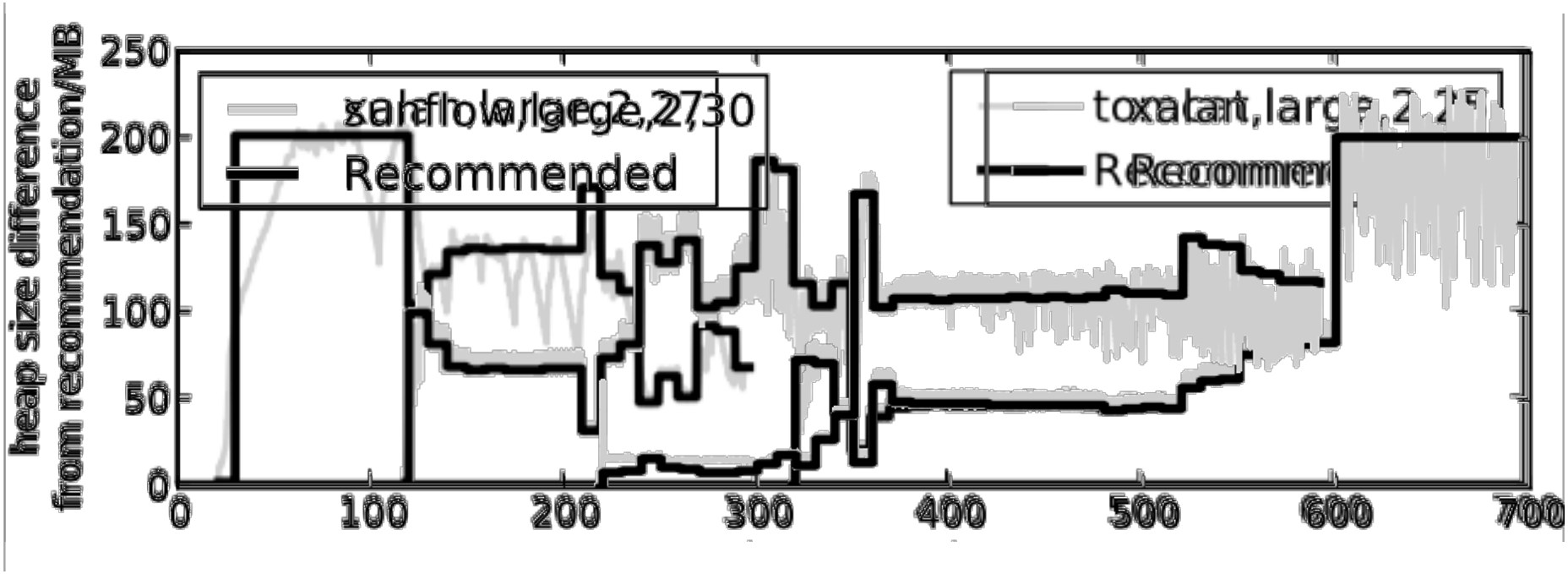

heap size difference
from recommendation/MB
250
200
150
100
50
0
0
100
200
300
400
500
600
700
tomcat,large,2,15
Recommended

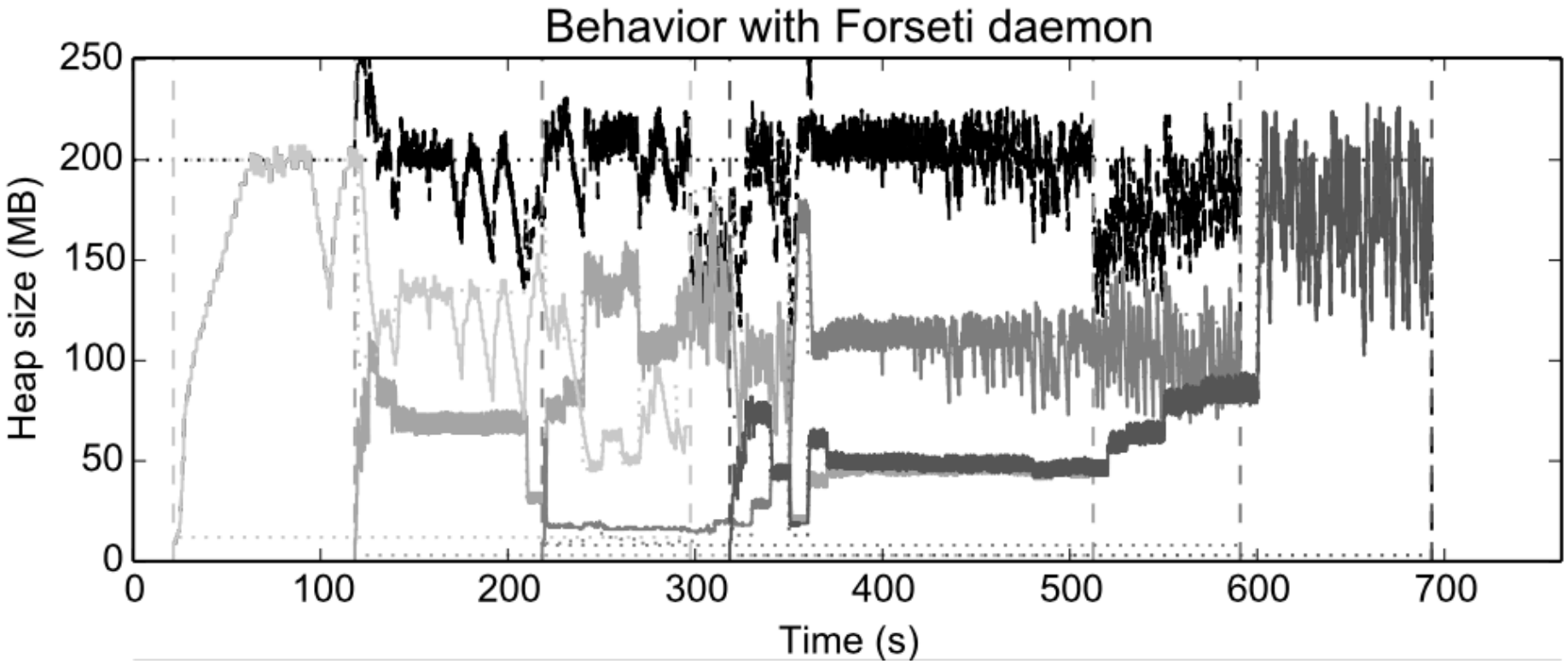

heap size difference
from recommendation/MB
250
200
150
100
50
0
0
100
200
300
400
500
600
700
xalan,large,2,27
Recommended

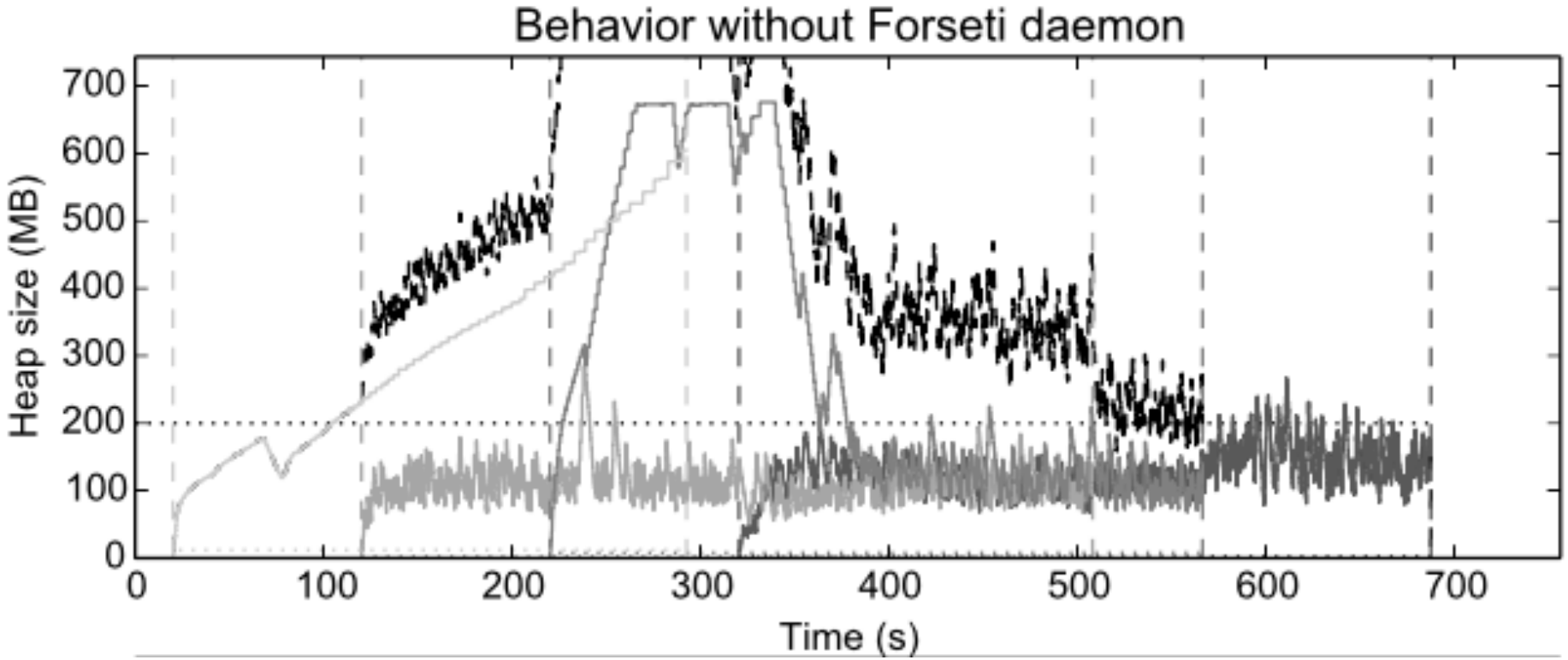

heap size difference
from recommendation/MB
250
200
150
100
50
0
0
100
200
300
400
500
600
700
sunflow,large,2,30
Recommended


heap size difference
from recommendation/MB
250
200
150
100
50
0
0
100
200
300
400
500
600
700
xalan,large,2,27
Recommended

OHP slide reminiscence…



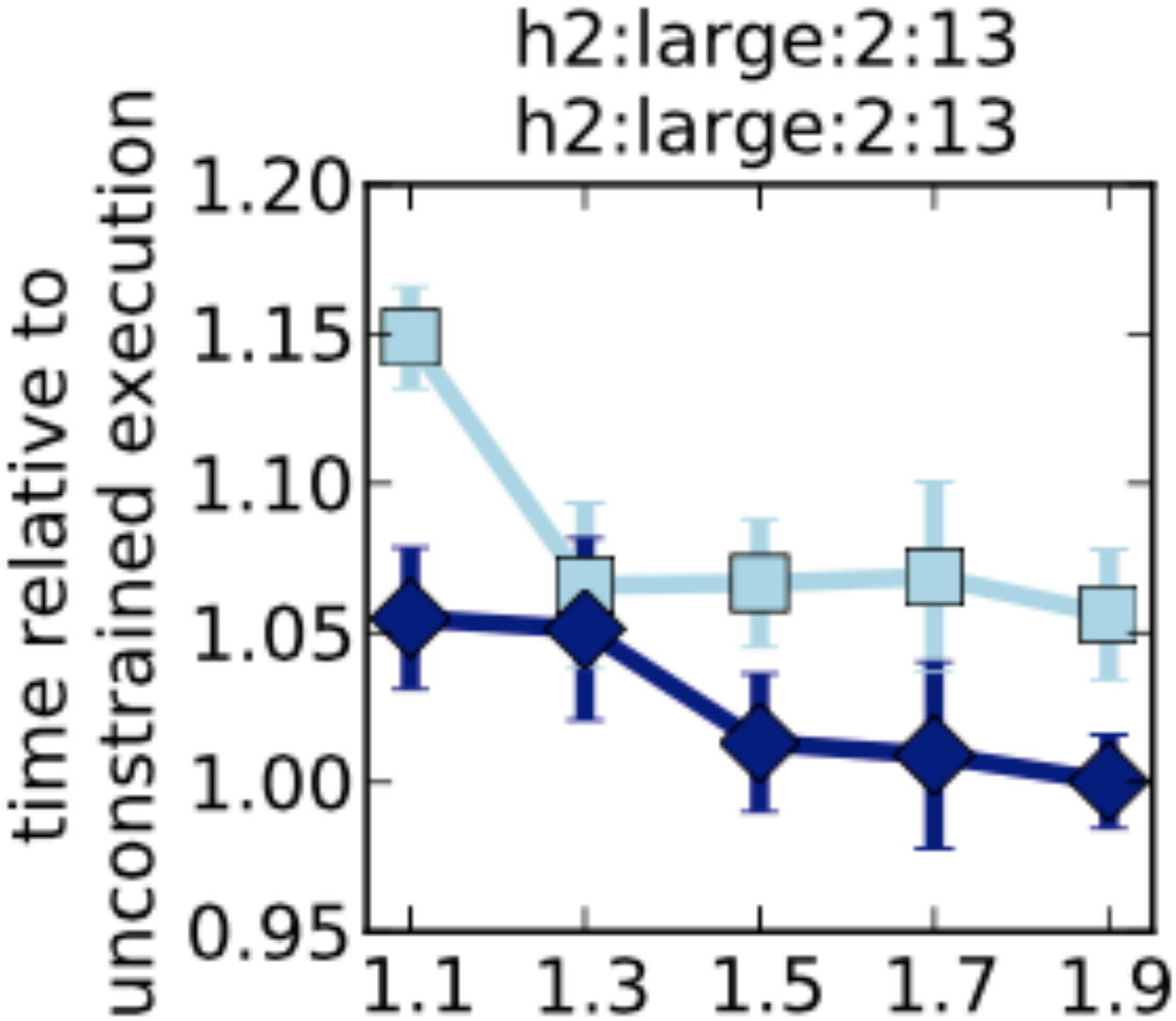

Behavior with Forseti daemon
Heap size (MB)
250
200
150
100
50
0
0
100
200
300
400
500
600
700
Time (s)


Behavior without Forseti daemon
Heap size (MB)
0
100
200
300
400
500
600
700
Time (s)

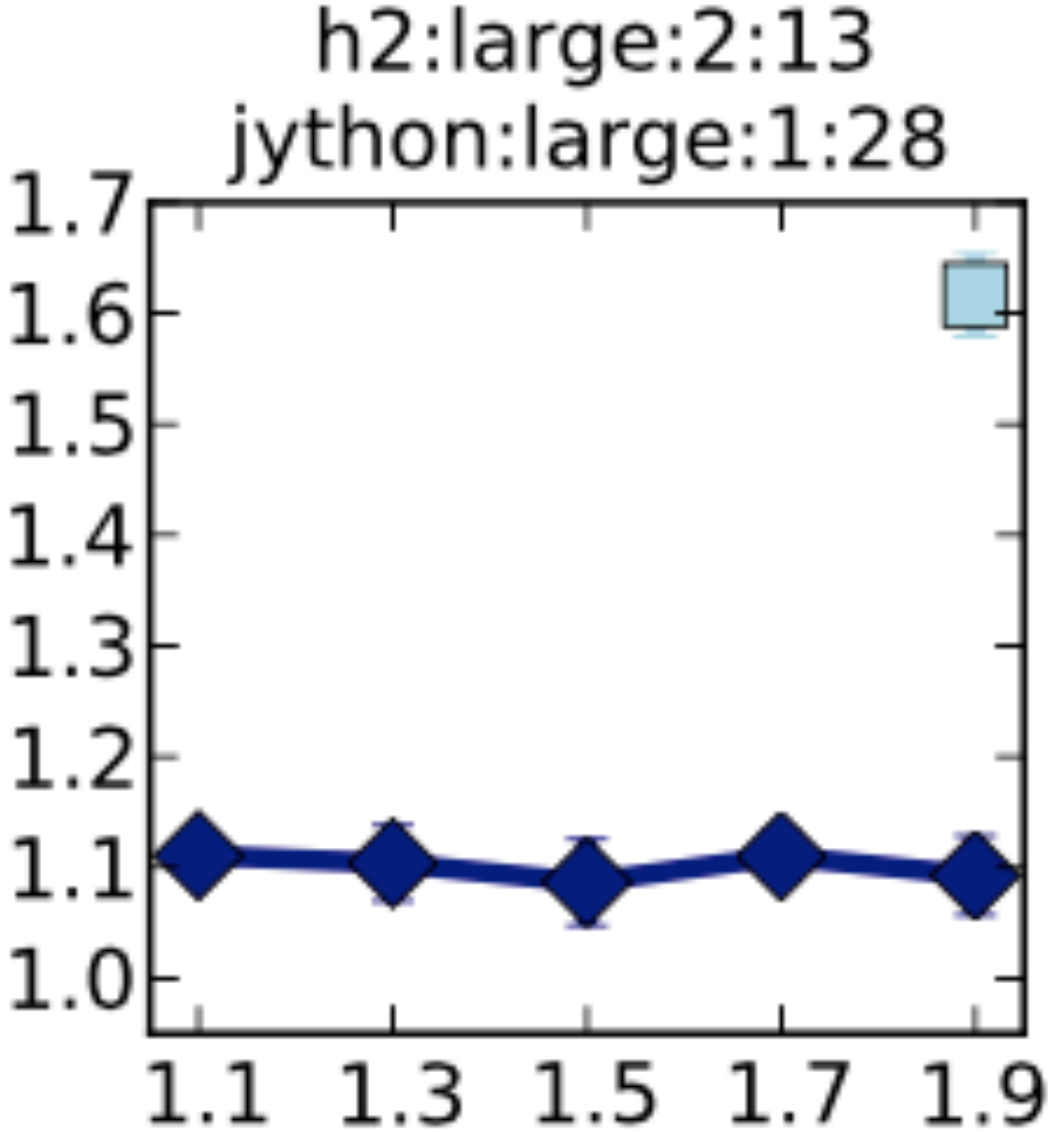
Experiment 2:

- run pairs of Java benchmarks concurrently
- Set target total mem usage to 1.1..1.9 x Σ minheaps
- compare execution time with
  - Forseti
  - Static fixed heaps
  - Less constrained sizing

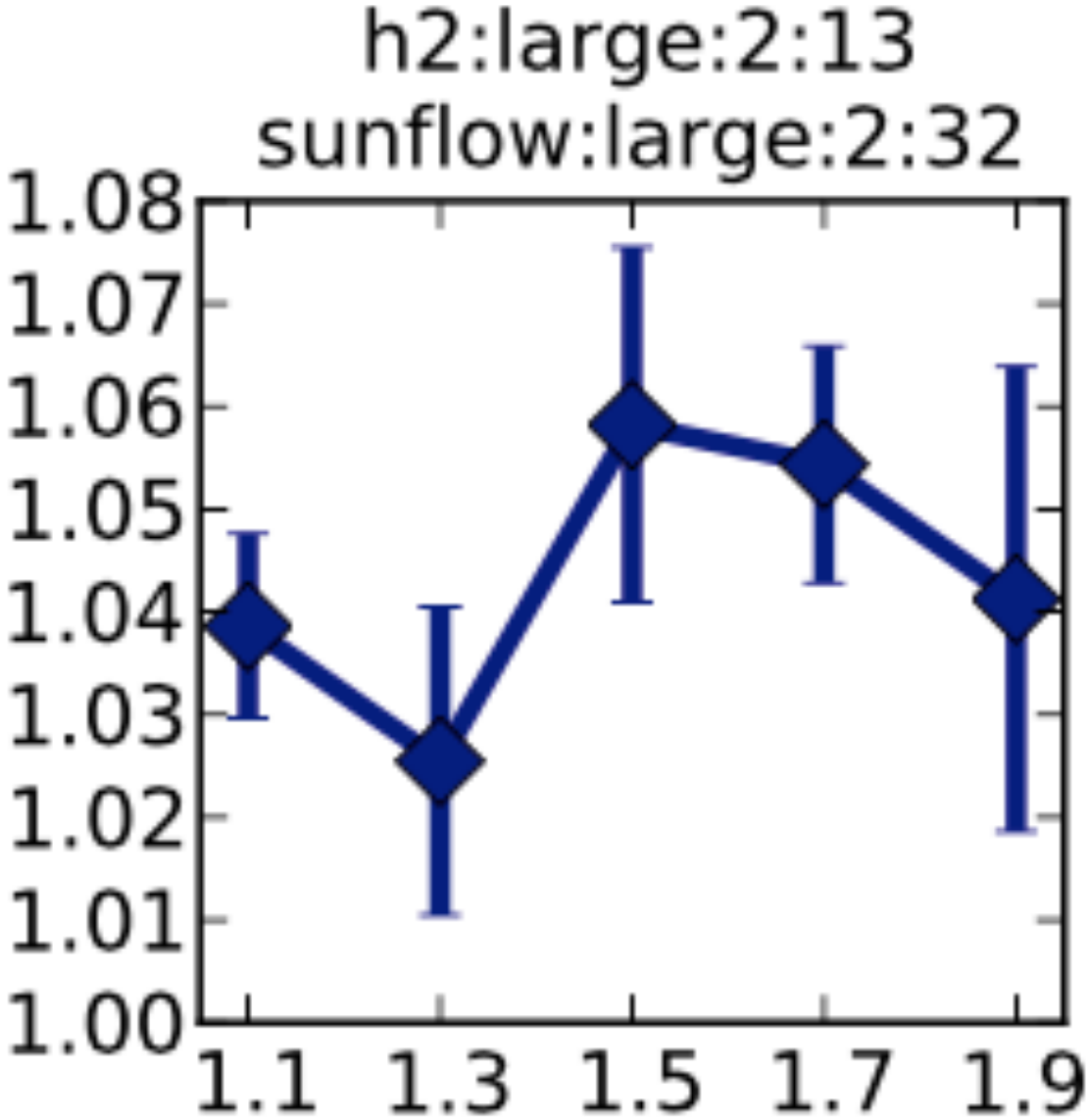
Relative Performance



Relative Performance



Relative Performance



Overheads

In all reported experiments, the time overhead for running the Forseti daemon is small. We analyzed the 6104 experimental runs completed for this paper:

- mean experiment wall clock time is 412 seconds (max is 2300 seconds).
- mean daemon CPU time is 1.00 seconds (max is 5.94 seconds).
- mean daemon memory footprint is 23MB (max is 29MB).

Conclusions

Garbage Collectors require *Holistic* Systems Optimization

- Model must consider all VMs in system
- Optimize holistically, not in isolation

- Is this a new OS service?
- Generalizability?

end of presentation

Trust Issues

- Can Forseti trust VM readings?
  - spoofing or denial-of-service attacks
  - use other metrics (performance counters)
- Can VMs ignore Forseti advice?
  - yes, at present
  - but Forseti could interact with the OS mem mgr to be more aggressive

Alternative Utility Functions

Benthamite (utilitarian – maximize total utility)

$$W = \sum_{i=1}^{n} Y_i$$

Rawlsian (consider least well-off individual)

$$W = \min(Y_1, Y_2, \cdots, Y_n)$$

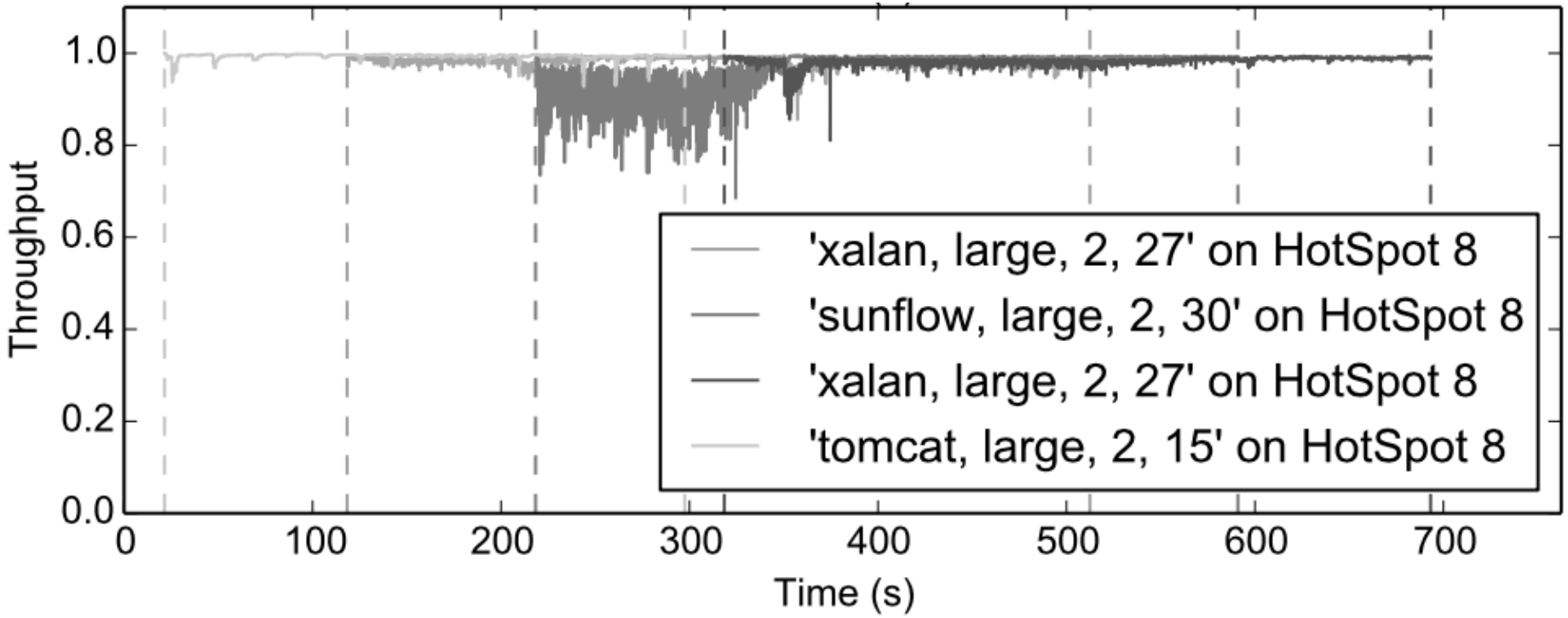
Related Work

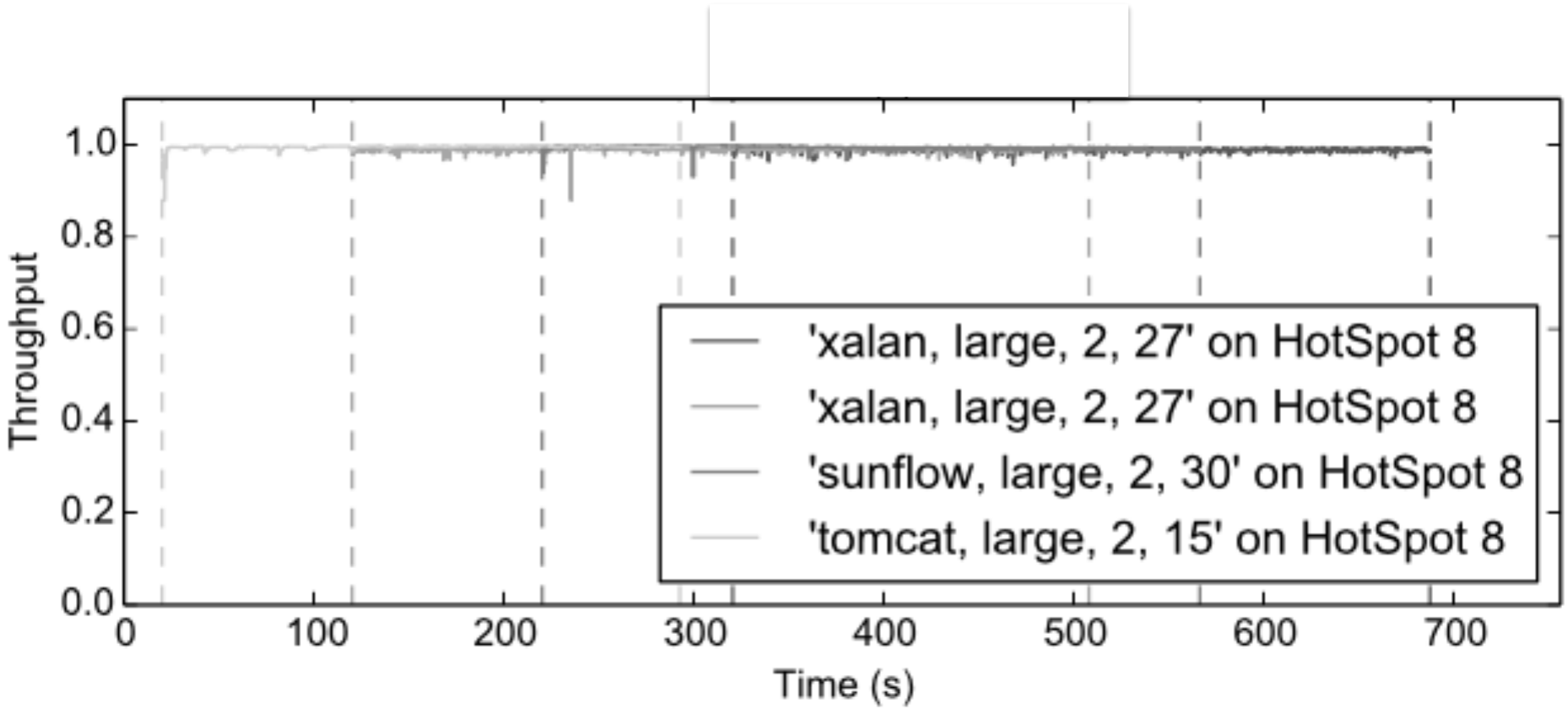
- Alonso and Appel [SIGMETRICS 1990]
  - their advisor daemon works to prevent paging in SML/NJ runtimes due to excessive heap growth
  - advice not based on economic utility model explicitly

get our code

https://bitbucket.org/jsinger/economics_memory_code

Throughput for staggered multi-VM experiment




Throughput
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
700
Time (s)
'xalan, large, 2, 27' on HotSpot 8
'xalan, large, 2, 27' on HotSpot 8
'sunflow, large, 2, 30' on HotSpot 8
'tomcat, large, 2, 15' on HotSpot 8