bellsoft

PROFILE YOUR NATIVE IMAGE

Dmitry Chuyko

bell-sw.com | 2025

bellsoft

WHO WE ARE

Dmitry Chuyko

https://openjdk.org/census#dchuyko

About BellSoft

bell//soft

BellSoft was founded in 2017 by Java and Linux experts with 15+ years of experience working in Sun/Oracle.
Headquarters in San Jose, California.

Members of:

- JCP Executive Committee
- OpenJDK Vulnerability Group
- GraalVM Advisory Board
- Linux Foundation
- Cloud Native Computing Foundation

Our products

bellsoft

Java

Liberica JDK is a 100% open-source vanilla Java 8, 11, 17 and 21 implementation.

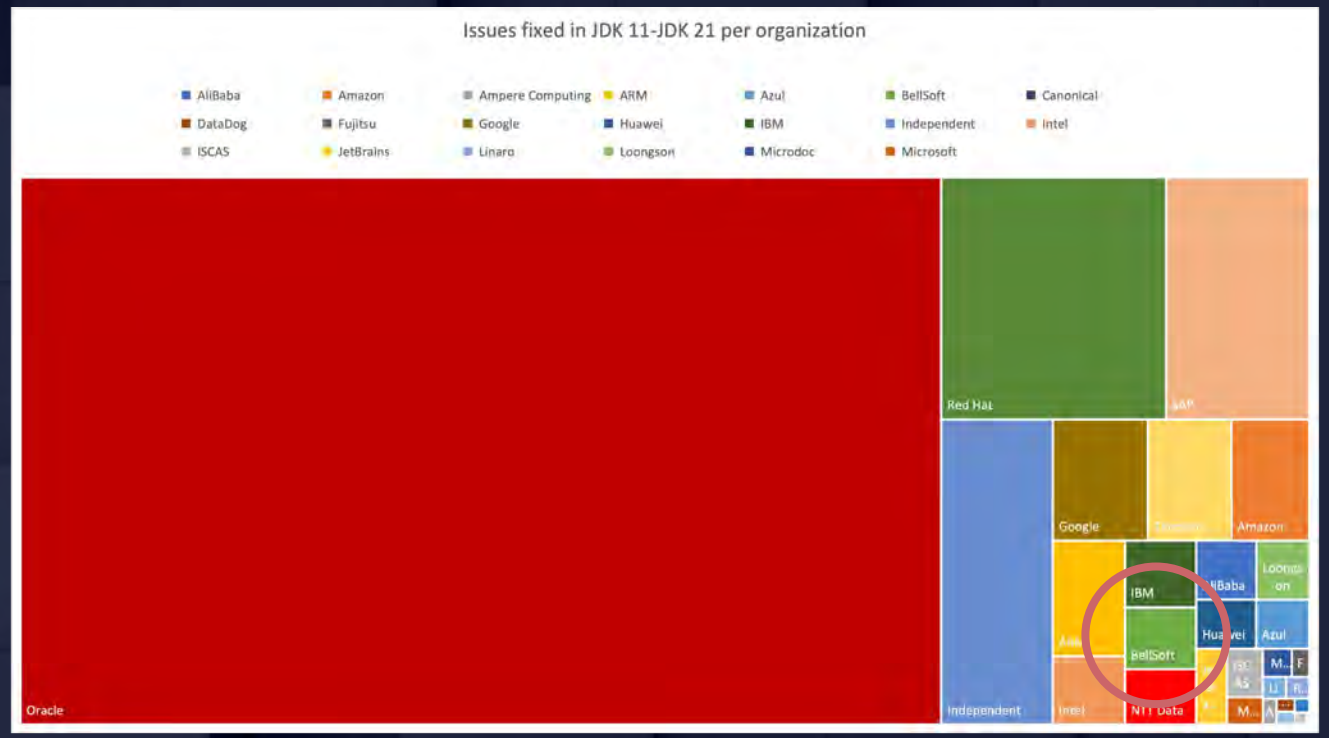
Liberica Native Image Kit JDK is a GraalVM based tool for creating performant native images.

Release schedule for all the products conforms to the LTS roadmap.
All products are available for a large number of platforms.

Linux

Alpaquita Linux is 100% Alpine compatible, secure, and optimized for Java.

bell//soft



BellSoft's contributions to OpenJDK

- Leading OpenJDK contributor
- JEP 315 (aarch64 optimization)
- JEP 386 (Alpine Linux port)
- Maintain the upstream Arm port
- Brought musl libc support to GraalVM

GraalVM Native Image

Standalone executable

- No OpenJDK runtime
- Closed world assumption
- Special treatment of dynamic features

Benefits

- Instant warmup
- Lower footprint
- High performance
- Great for the Cloud

OPTIMIZE APPLICATION?

TIME FOR PROFILING


THE APP

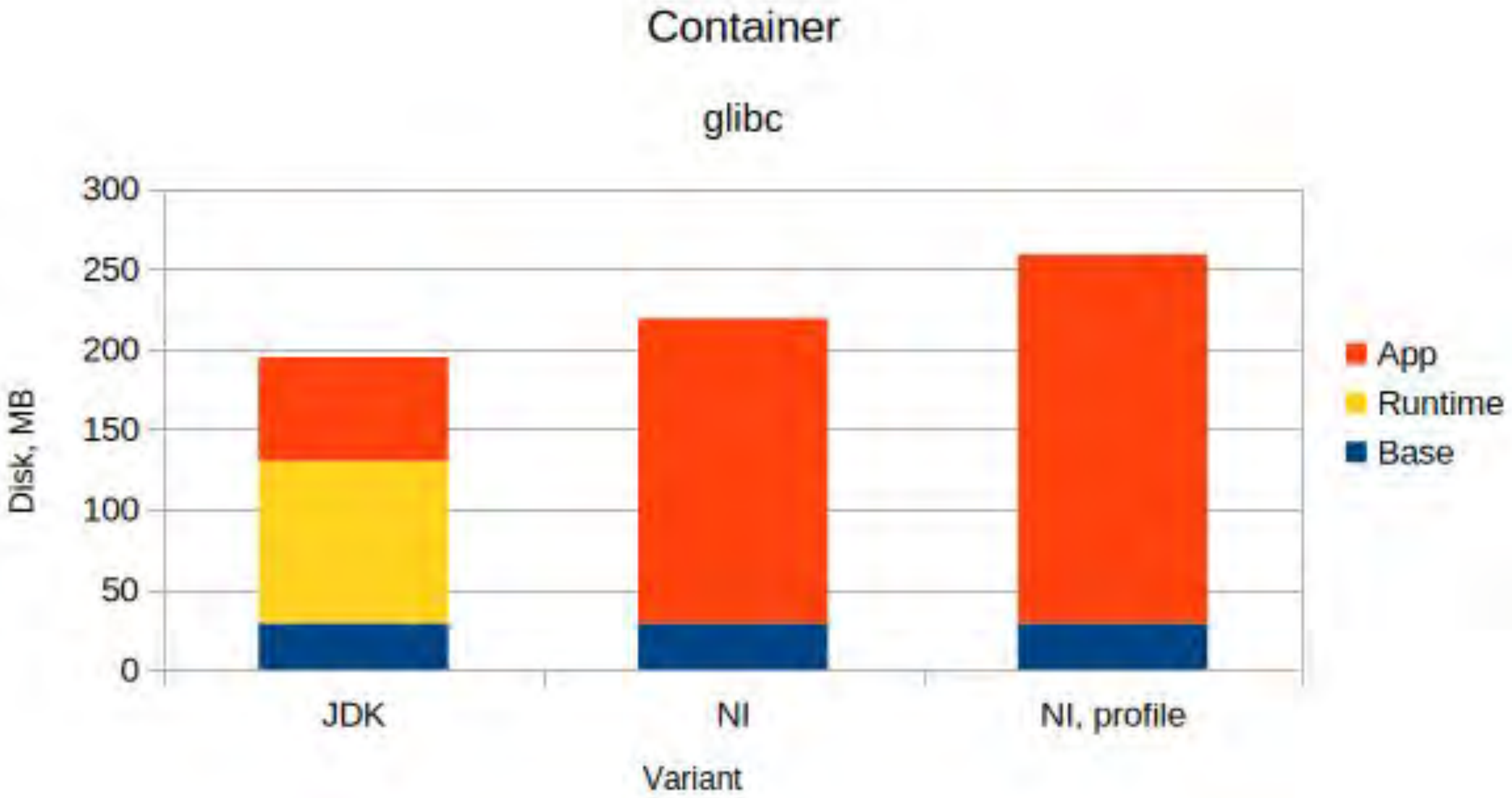
Spring Boot PetClinic

3.5.0-SNAPSHOT

Liberica NIK 24.0.1+11-24.2.1
Liberica JDK 24.0.1

pom.xml /build/plugins

```
<plugin>
  <groupId>org.graalvm.buildtools</groupId>
  <artifactId>native-maven-plugin</artifactId>
  <configuration>
    <buildArgs>
      <buildArg>--enable-monitoring=all</buildArg>
      <buildArg>-H:+PreserveFramePointer</buildArg>
      <buildArg>-g</buildArg>
      <buildArg>-H:+SourceLevelDebug</buildArg>
      <buildArg>-H:-DeleteLocalSymbols</buildArg>
    </buildArgs>
  </configuration>
</plugin>
```

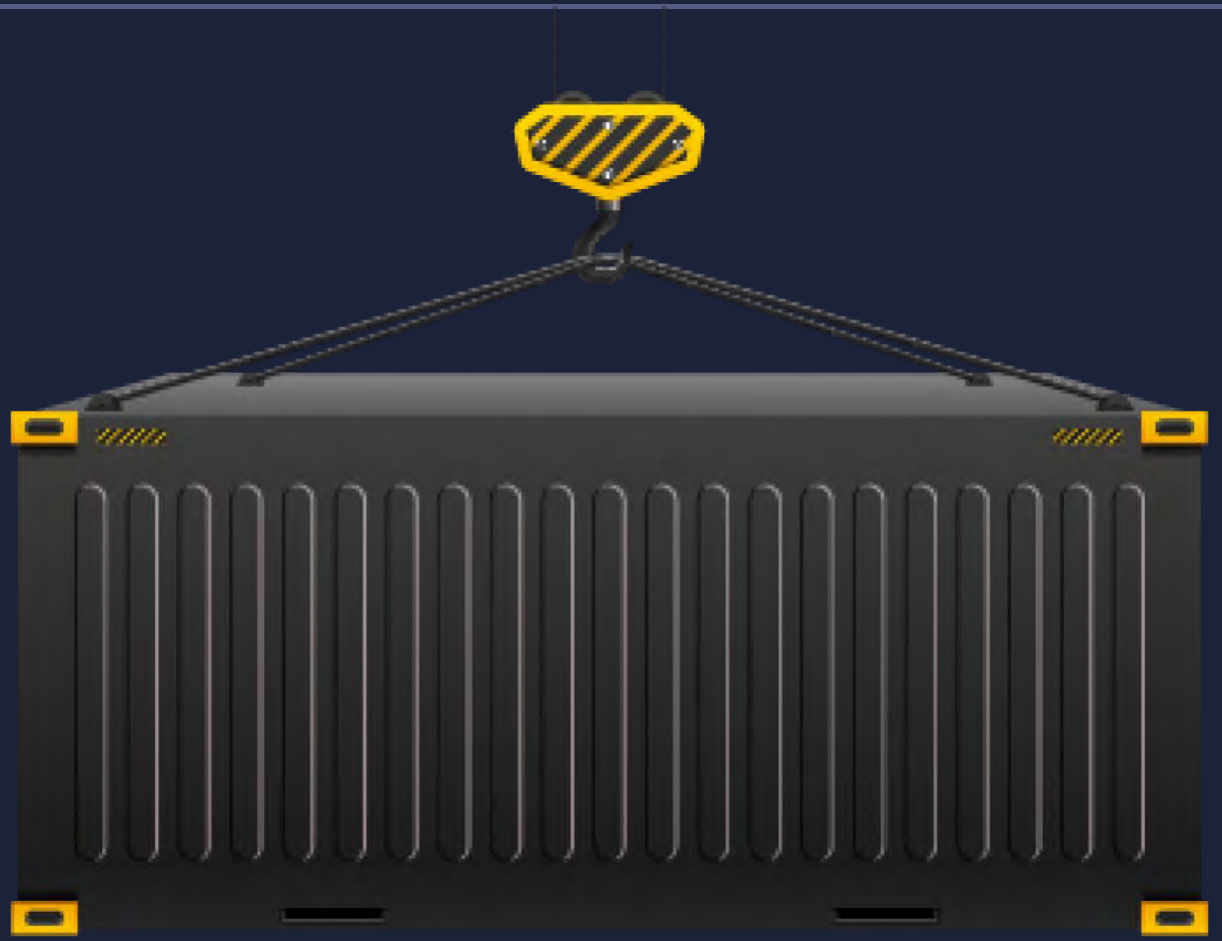

Container
glibc
300
250
200
150
100
50
0
Disk, MB
JDK
NI
NI, profile
Variant
App
Runtime
Base

Tunings Parity

```
-XX:+UseSerialGC
-XX:MaxRAMPercentage=80
-XX:+UnlockDiagnosticVMOptions
-XX:+PreserveFramePointer
-XX:+DebugNonSafepoints
-XX:NativeMemoryTracking=summary
-XX:+PrintNMTStatistics
```

```
-XX:MaximumHeapSizePercent=80
-XX:+PrintNMTStatistics
```

4 CPUs 8GB (no swap)



Service Load

WRK2 + HdrHistogram

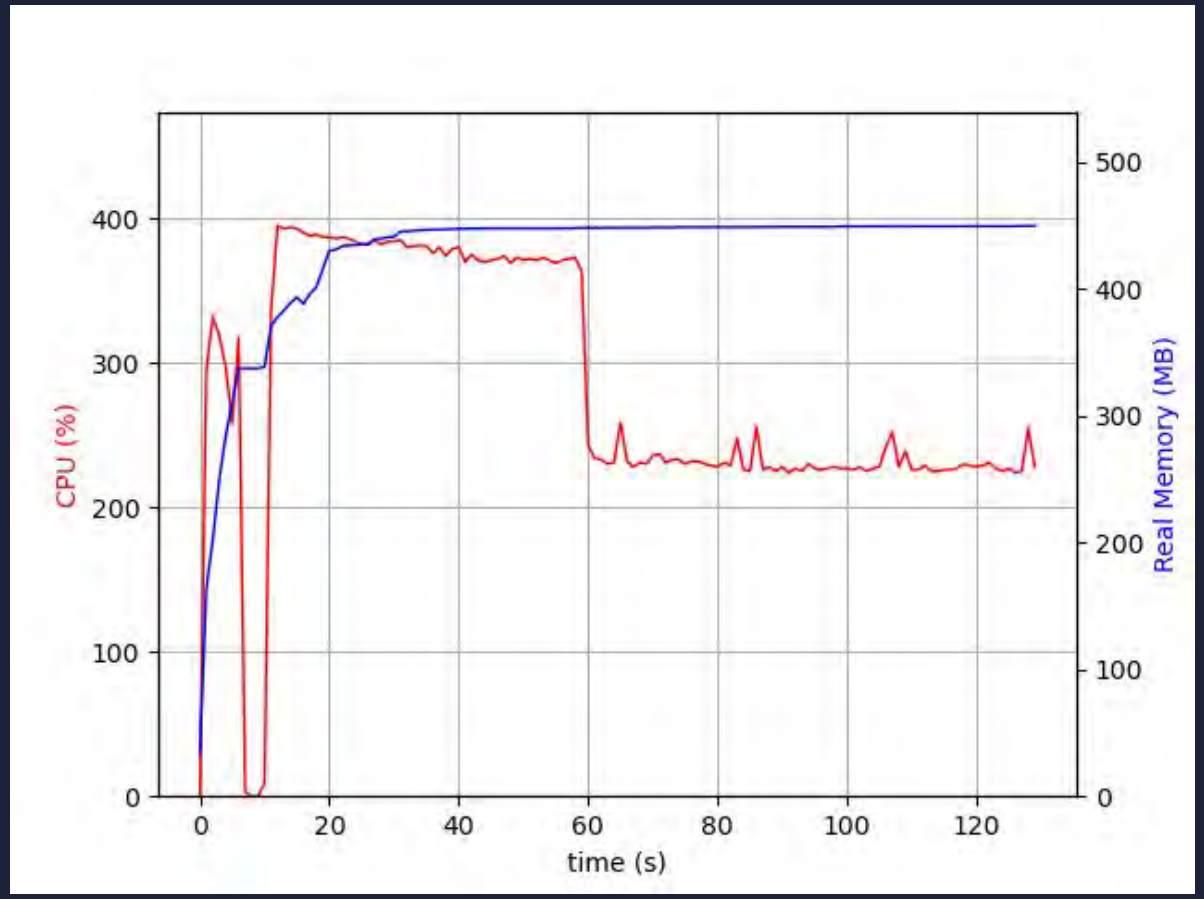
Fixed rate (500 RPS)

Query all default pet owners
– Low GC pressure

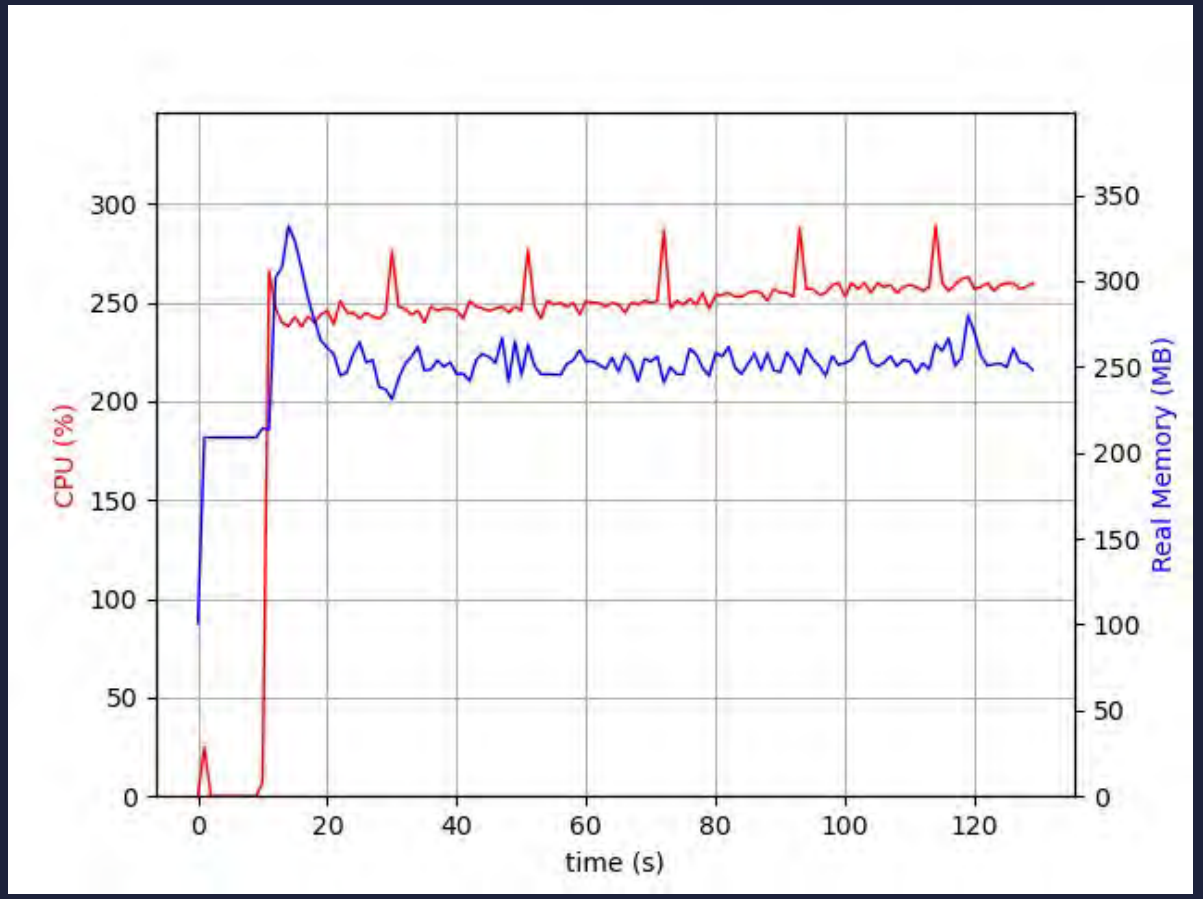
Warmup study

Latency measurement
2 `wrk` threads, 10 connections

Server VM

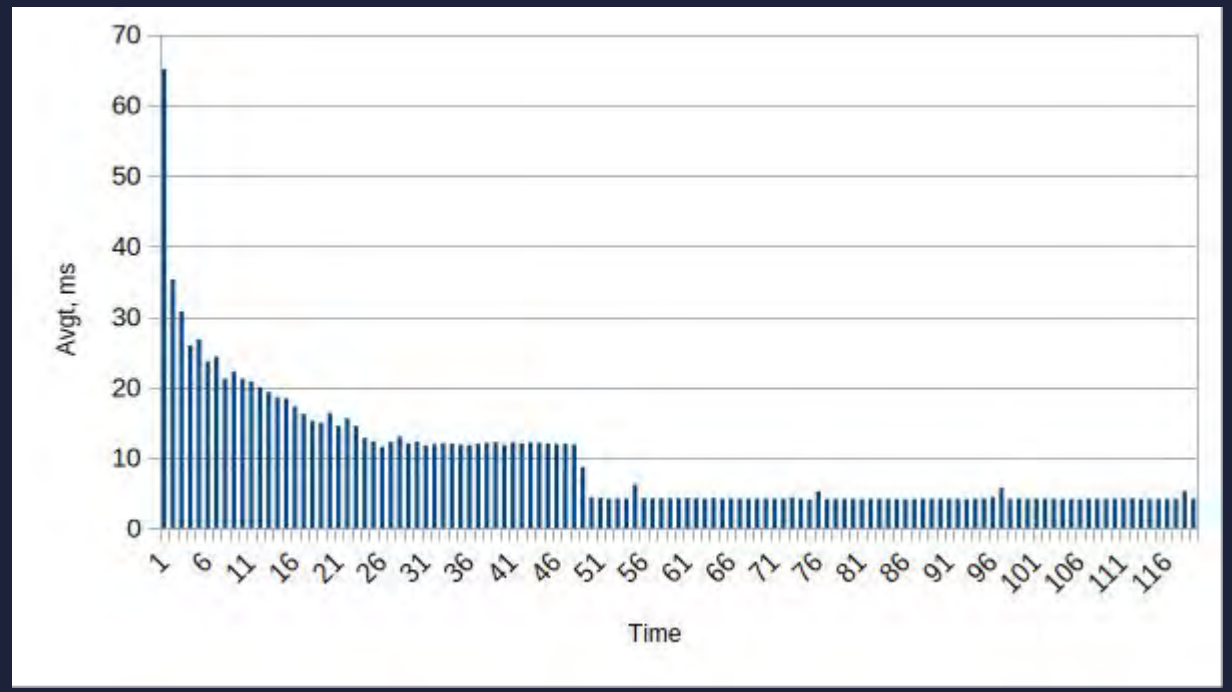


Native Image (release)



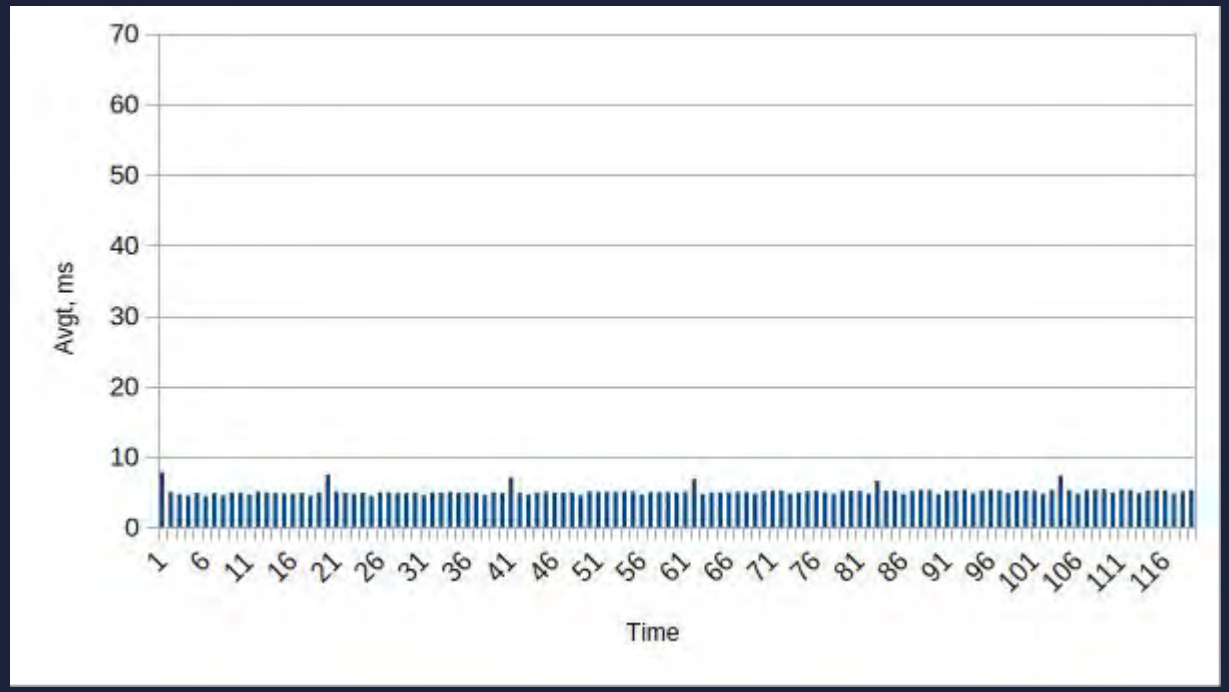
Run time. psrecord

Server VM



p99.9 (warm) 34.14ms

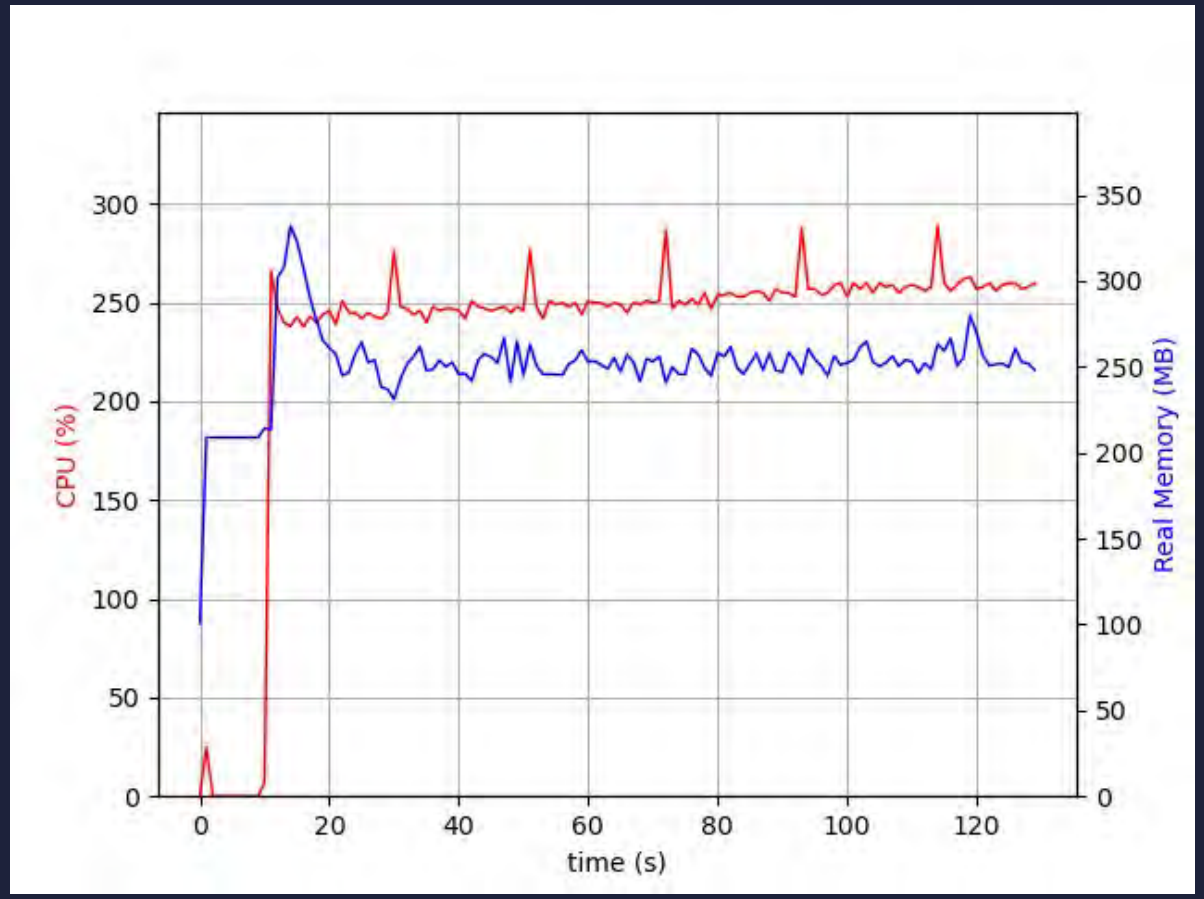
Native Image (release)



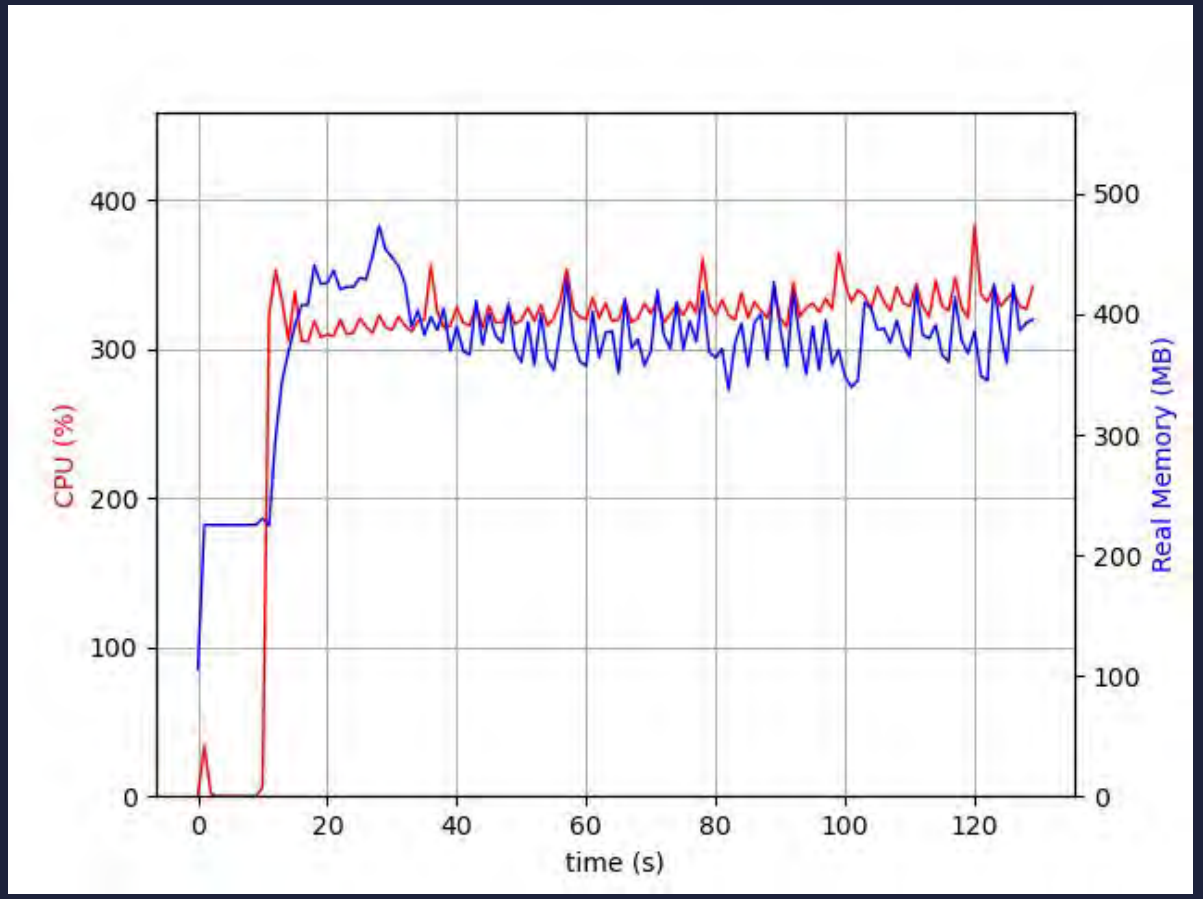
p99.9 48.38ms

Run time. access logs, hdr

Native Image (release)

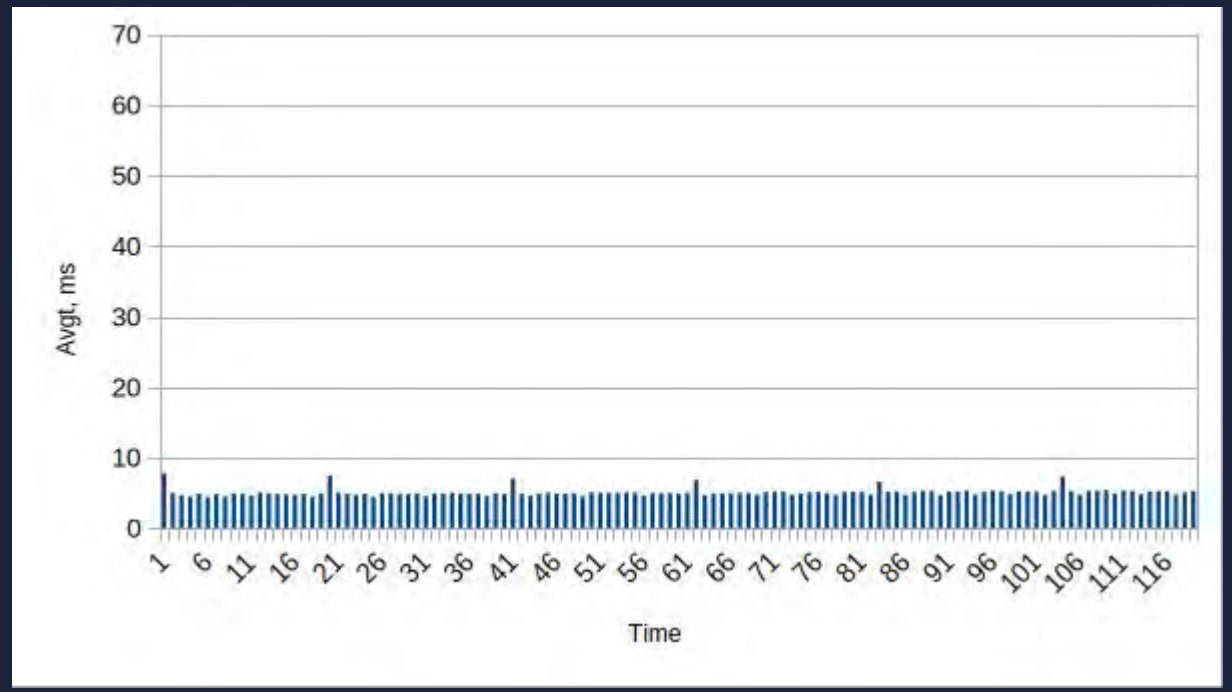


Native Image (full diagnostics)



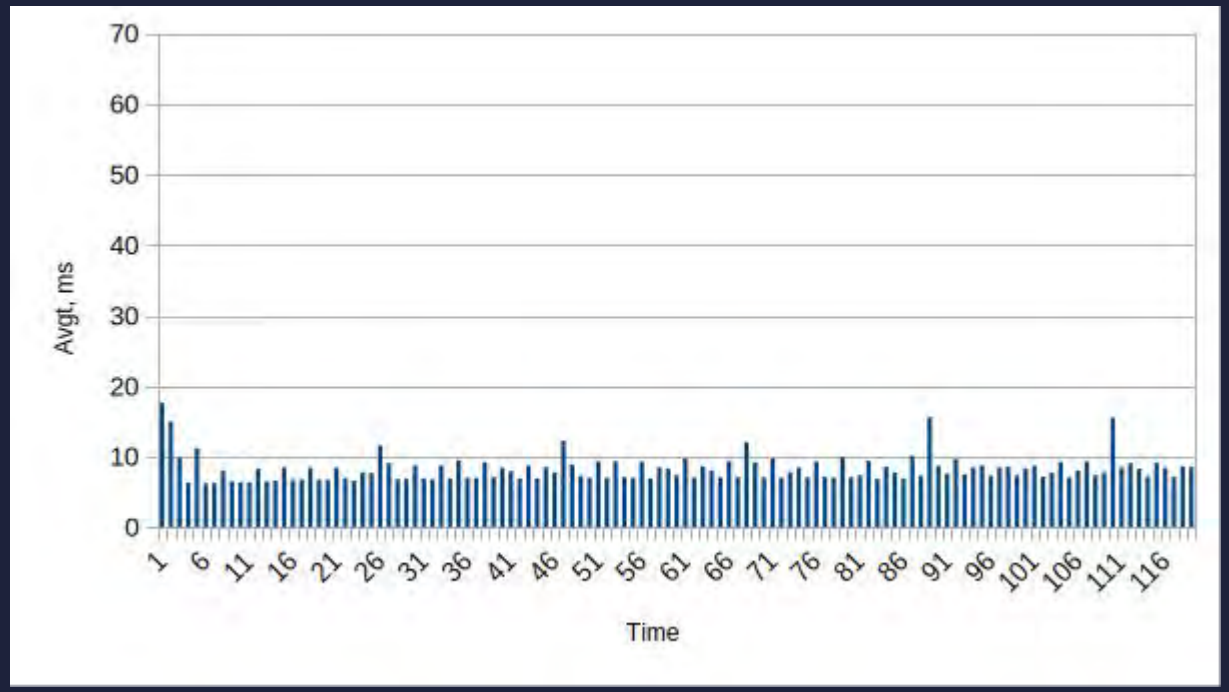
Run time. psrecord

Native Image (release)



p99.9 48.38ms

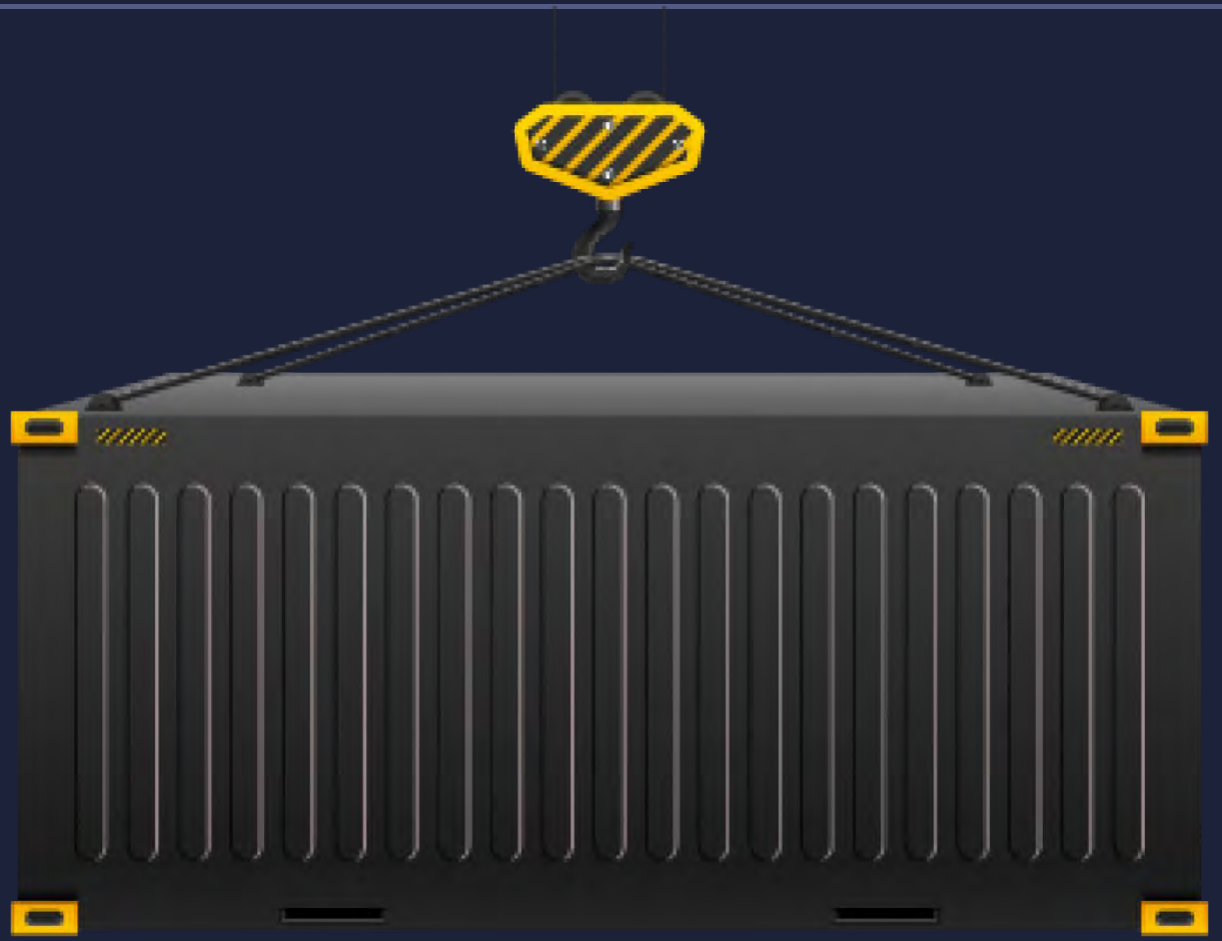
Native Image (full diagnostics)



p99.9 107.33ms

Run time. access logs, hdr

2 CPUs 1GB (no swap)



Service Load

WRK2 + HdrHistogram

Fixed rate (250 RPS)

Query all default pet owners
  – Low GC pressure

Warmup study

Latency measurement
2 `wrk` threads, 10 connections

More Diagnostics in Containers

```
-p 9010:9010

-Dcom.sun.management.jmxremote.authenticate=false
-Djava.rmi.server.hostname=localhost
-Dcom.sun.management.jmxremote
-Dcom.sun.management.jmxremote.port=9010
-Dcom.sun.management.jmxremote.rmi.port=9010
-Dcom.sun.management.jmxremote.ssl=false
-Dcom.sun.management.jmxremote.local.only=false
```


VISUALVM

Some CLI First

```
$ jps
587980 Jps

$ sudo jps
587305 PetClinicApplication
588017 Jps
587172 spring-petclinic-3.5.0-SNAPSHOT.jar
```

Some CLI First

```
$ sudo jstat -gc <jvm|ni>
```

S0C	S1C	S0U	S1U	EC	EU	OC	OU	MC	MU	CCSC	CCSU	YGC	YGCT	FGC	FGCT	CGC	CGCT	GCT
7744.0	7744.0	0.0	76.5	62400.0	59372.0	155648.0	35573.5	104512.0	103858.8	11008.0	10741.6	2003	2.861	4	0.161	-	-	3.022

Stack Traces

```
sudo kill -3 <jvm>

Full thread dump OpenJDK 64-Bit Server VM (24.0.1+13 mixed mode):

Threads class SMR info:
_java_thread_list=0x00007746800027e0, length=28, elements={
0x00007746e40e66a0, 0x00007746e40e7e80, 0x00007746e40f27e0,
0x00007746e40ea300,
.....
    at java.lang.Thread.run(java.base@24.0.1/Thread.java:1447)

"VM Thread" os_prio=0 cpu=3111.86ms elapsed=2652.01s tid=0x00007746e40724d0
nid=9 runnable

"VM Periodic Task Thread" os_prio=0 cpu=1414.07ms elapsed=2652.02s
tid=0x00007746e4054c90 nid=8 waiting on condition

JNI global refs: 12, weak refs: 0

Heap
 DefNew         total 70144K, used 943K [0x000000526a00000, 0x000000052b610000,
```

Stack Traces

```
sudo kill -3 <ni>

Full thread dump:

"http-nio-8080-exec-13" #75 daemon thread=0x0000783960000b80 state=WAITING
....
  A  SP 0x0000783995efee60 IP 0x0000000000fb8a27 size=32
com.oracle.svm.core.thread.PlatformThreads.threadStartRoutine(PlatformThreads.
java:813)
  A  SP 0x0000783995efee80 IP 0x0000000000e0a604 size=96
com.oracle.svm.core.code.IsolateEnterStub.PlatformThreads_threadStartRoutine_Z
5jZ9wXZGDAvr0CL8KrTOA(IsolateEnterStub.java:0)
```

$ sudo jcmd <host pid> help

```
Compiler.CodeHeap_Analytics
Compiler.codecache
Compiler.codelist
Compiler.directives_add
Compiler.directives_clear
Compiler.directives_print
Compiler.directives_remove
Compiler.memory
Compiler.perfmap
Compiler.queue
GC.class_histogram
GC.finalizer_info
GC.heap_dump
GC.heap_info
GC.run
GC.run_finalization
JFR.check
JFR.configure
JFR.dump
JFR.start
JFR.stop
JFR.view
JVMTI.agent_load
JVMTI.data_dump
ManagementAgent.start
ManagementAgent.start_local
ManagementAgent.status
ManagementAgent.stop
System.dump_map
System.map
System.native_heap_info
System.trim_native_heap
Thread.dump_to_file
Thread.print
Thread.vthread_pollers
Thread.vthread_scheduler
VM.cds
VM.class_hierarchy
VM.classes
VM.classloader_stats
VM.classloaders
VM.command_line
VM.dynlibs
VM.events
VM.flags
VM.info
VM.log
VM.metaspace
VM.native_memory
VM.set_flag
VM.stringtable
VM.symboltable
VM.system_properties
VM.systemdictionary
VM.uptime
VM.version
help
```

```
GC.heap_dump
GC.run
JFR.start
JFR.stop
JFR.check
JFR.dump
Thread.dump_to_file
Thread.print
VM.command_line
VM.native_memory
VM.system_properties
VM.uptime
VM.version
help
```

VisualVM 2.2

File Applications View Tools Window Help

Applications

- Local
  - VisualVM
  - org.springframework.samples.petclinic.PetCli
  - spring-petclinic-3.5.0-SNAPSHOT.jar (pid 1)
  - spring-petclinic-3.5.0-SNAPSHOT.jar (pid 5980
  - localhost:9012 (pid 1)
- Remote
- VM Coredumps
- JFR Snapshots
- Snapshots

Start Page | spring-petclinic-3.5.0-SNAPSHOT.jar (pid 1) | localhost:9012 (pid 1)

Overview | Monitor | Threads | Sampler

spring-petclinic-3.5.0-SNAPSHOT.jar (pid 1)

Sampler — Settings

Sample: CPU | Memory | Stop

Status: sampling inactive

CPU samples | Thread CPU time

Results: Statistics: Threads Count: 36 Total Time (CPU): 168,217 ms — Thread Dump

Name	Thread Time (CPU)	Thread Time (CPU) / sec
http-nio-8080-exec-8	13,493 ms (8%)	94.9 ms (9.5%)
http-nio-8080-exec-4	13,410 ms (8%)	105 ms (10.6%)
http-nio-8080-exec-9	13,391 ms (8%)	93.9 ms (9.4%)
http-nio-8080-exec-10	13,360 ms (7.9%)	111 ms (11.2%)
http-nio-8080-exec-1	13,343 ms (7.9%)	109 ms (11%)
http-nio-8080-exec-5	13,328 ms (7.9%)	104 ms (10.4%)
http-nio-8080-exec-11	13,202 ms (7.8%)	76.3 ms (7.6%)
http-nio-8080-exec-3	13,195 ms (7.8%)	83.1 ms (8.3%)
http-nio-8080-exec-2	13,016 ms (7.7%)	88.9 ms (8.9%)
http-nio-8080-exec-7	13,012 ms (7.7%)	87.7 ms (8.8%)
http-nio-8080-exec-12	12,936 ms (7.7%)	105 ms (10.5%)
http-nio-8080-exec-6	12,880 ms (7.7%)	95.7 ms (9.6%)
DestroyJavaVM	5,247 ms (3.1%)	0.0 ms (0%)
RMI TCP Connection(12)-172.17.0.1	1,942 ms (1.2%)	34.3 ms (3.4%)
http-nio-8080-Poller	1,111 ms (0.7%)	7.65 ms (0.8%)
RMI TCP Connection(13)-172.17.0.1	486 ms (0.3%)	0.0 ms (0%)
Notification Thread	270 ms (0.2%)	2.9 ms (0.2%)

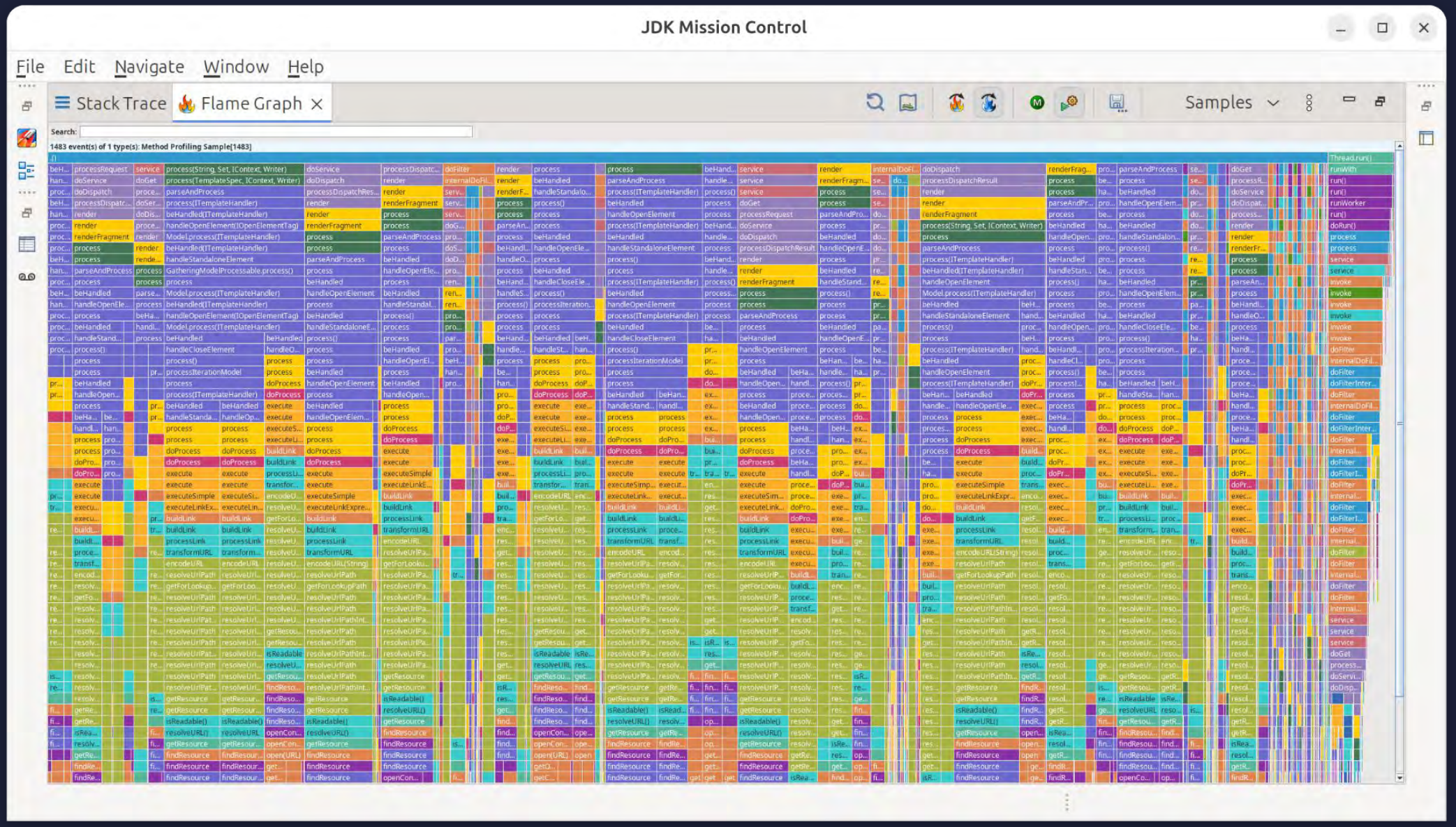

VisualVM 2.2
File Applications View Tools Window Help
Applications
Local
VisualVM
org.springframework.samples.petclinic.PetCli
spring-petclinic-3.5.0-SNAPSHOT.jar (pid 1)
spring-petclinic-3.5.0-SNAPSHOT.jar (pid 5980
localhost:9012 (pid 1)
Remote
VM Coredumps
JFR Snapshots
Snapshots
Start Page
spring-petclinic-3.5.0-SNAPSHOT.jar (pid 1)
localhost:9012 (pid 1)
Overview
Monitor
Threads
localhost:9012 (pid 1)
Monitor
CPU
Memory
Classes
Threads
Uptime: 23 min 16 sec
Perform GC
Heap Dump
CPU
CPU usage: 98.2%
GC activity: 1.1%
100%
80%
60%
40%
20%
0%
3:10:00 AM
0:10 AM
0:20 AM
0:30 AM
0:40 AM
0:50 AM
1:00 AM
1:10 AM
CPU usage
GC activity
Heap
N/A
Size: 262,275,112 B
Used: 50,987,048 B
Max: 12,236,357,632 B
300 MB
200 MB
100 MB
0 MB
Heap size
Used heap
Classes
Total loaded: 0
Shared loaded: 0
Total unloaded: 0
Shared unloaded: 0
100
80
60
40
20
0
Total loaded classes
Shared loaded classes
Threads
Live: 28
Daemon: 24
Live peak: 30
Total started: 42
30
20
10
0
Live threads
Daemon threads


JFR

JFR

```
$ sudo jcmd <host pid> JFR.start \
       filename=/target/jdk.jfr settings=profile duration=30s
```

Server VM

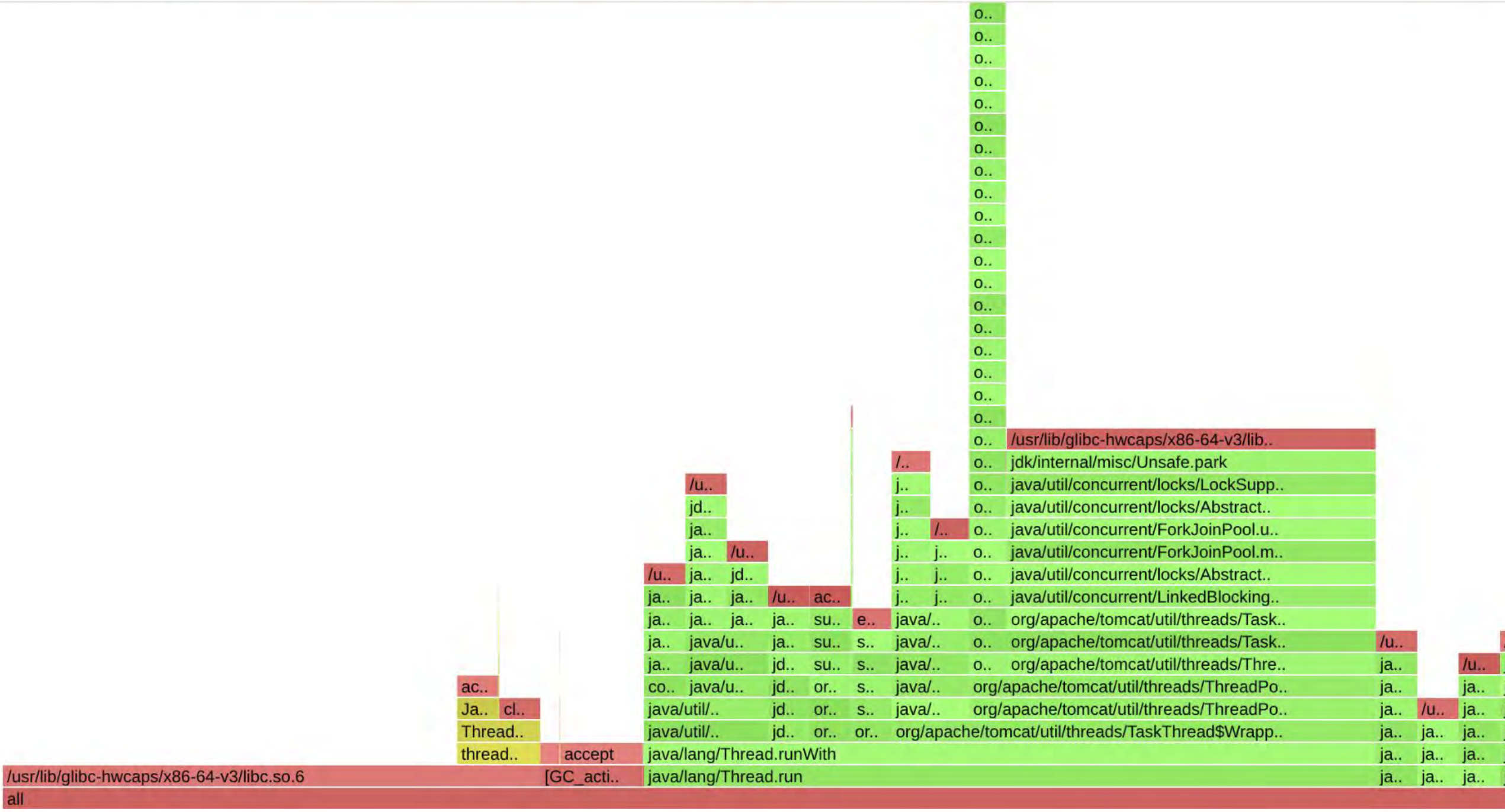

JDK Mission Control
File
Edit
Navigate
Window
Help
Stack Trace
Flame Graph
Samples
Search:
1483 event(s) of 1 type(s): Method Profiling Sample[1483]

Native Image (full diagnostics)


NATIVE TOOLS

async-profiler – JDK only

```
$ sudo async-profiler-4.0-linux-x64/bin/asprof \
    --libpath /target/async-profiler-4.0-linux-x64/lib/libasyncProfiler.so \
    -d 30 \
    -e wall \
    -f /target/async-jdk-wall.html <host pid>
```

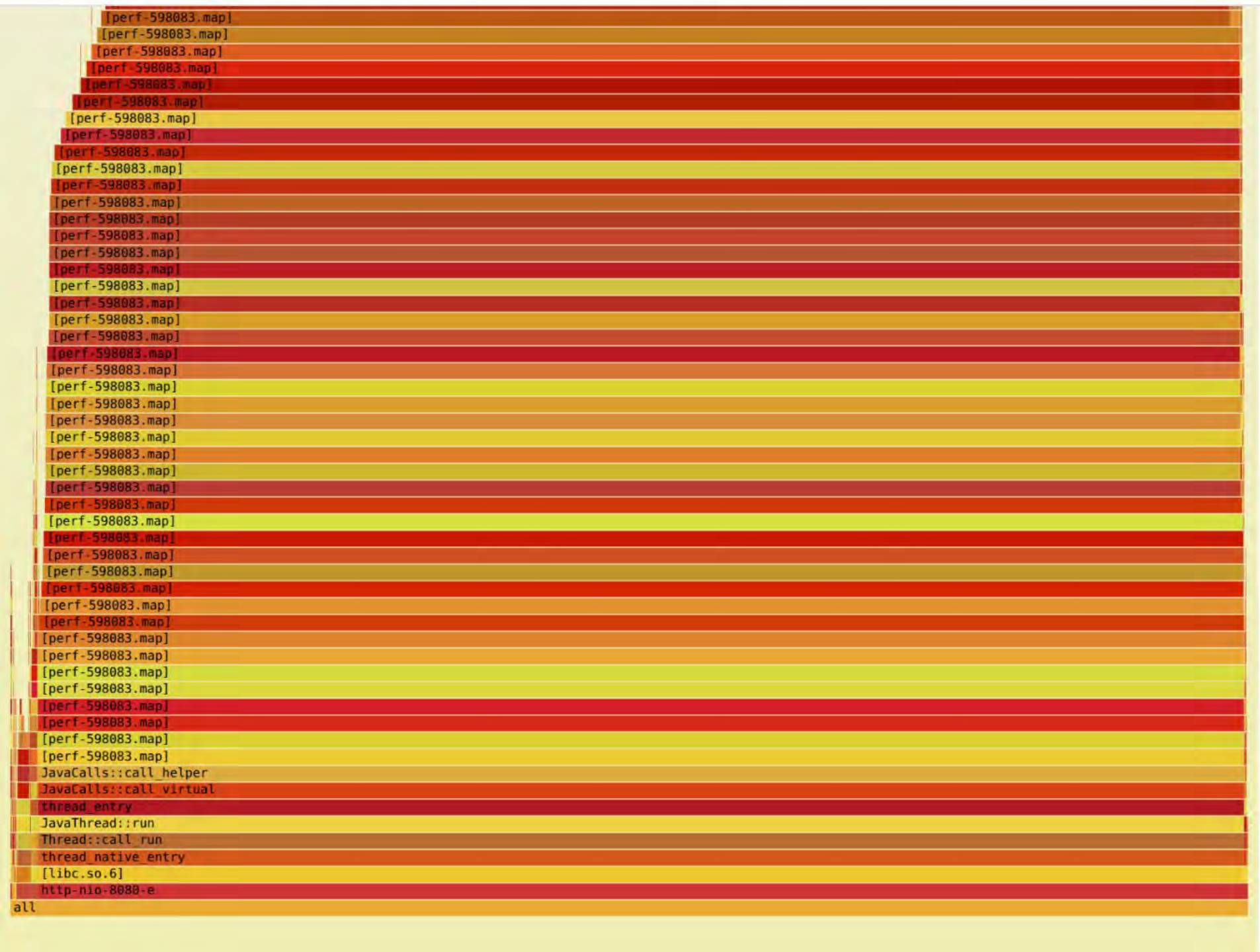

o..
/usr/lib/glibc-hwcaps/x86-64-v3/lib..
jdk/internal/misc/Unsafe.park
java/util/concurrent/locks/LockSupp..
java/util/concurrent/locks/Abstract..
java/util/concurrent/ForkJoinPool.u..
java/util/concurrent/ForkJoinPool.m..
java/util/concurrent/locks/Abstract..
java/util/concurrent/LinkedBlocking..
org/apache/tomcat/util/threads/Task..
org/apache/tomcat/util/threads/Thre..
org/apache/tomcat/util/threads/ThreadPo..
org/apache/tomcat/util/threads/TaskThread$Wrapp..
java/lang/Thread.runWith
java/lang/Thread.run
accept
[GC_acti..
/usr/lib/glibc-hwcaps/x86-64-v3/libc.so.6
all


jav..
o..
java..
or..
org/springfram..
j..
java/net/URL.o..
jdk/internal/loader..
jdk/internal/loader..
java/net/URLClassLo..
org/springframework..
java/lang/ClassLoad..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springframework..
org/springfr..
org/springfr..
java/net/URL..
jdk/internal/l..
jdk/internal/lo..
java/net/URLCla..
org/springframe..
java/lang/Class..
org/s..
java/n..
org/sp..
java/ne..
org/spr..
org/sprin..
org..
org/springframework/boot/loader/net/p..
java..
org/springframework/boot/loader/net/p..
java..
java/net/URL.openConnection
jdk/internal/loader/URLClassPath$Loader.findR..
jdk/internal/loader/URLClassPath.findResource
java/net/URLClassLoader.findResource
org/springframework/boot/loader/net/protocol/ja..
java/lang/ClassLoader.getResource
org/springframework/core/io/ClassPathResource.r..
org/springframework/core/io/ClassPathResource.i..
org/springframework/web/servlet/resource/PathRe..
org/springframework/web/servlet/resource/PathRe..
org/springframework/web/servlet/resource/PathRe..
org/springframework/web/servlet/resource/Abstra..
org/springframework/web/servlet/resource/Defaul..
org/springframework/web/servlet/resource/LiteWeb..
org/springframework/web/servlet/resource/Abstrac..
org/springframework/web/servlet/resource/Default..
org/springframework/web/servlet/resource/Caching..
j..
java/ut..
j..
org/spri..
o..
org/spring..
or..
org/spring..
or..
org/spring..
java/..
org/sp..
java/n..
o..
org/spr..
or..
java/n..
org..
org/spr..
or..
java/n..
org..
org/spr..
org/..
org/springframework/boot/lo..
java/n..
org/springframework/boot/lo..
java/n..
java/net/URL.openConnection
jdk/internal/loader/URLClassPath$Load..
jdk/internal/loader/URLClassPath.findRe..
java/net/URLClassLoader.findResource
org/springframework/boot/loader/net/pro..
java/lang/ClassLoader.getResource
org/springframework/core/io/ClassPathRes..
org/springframework/core/io/ClassPathRes..
org/springframework/web/servlet/resource/..
org/springframework/web/servlet/resource/..
org/springframework/web/servlet/resource/..

Linux perf etc.

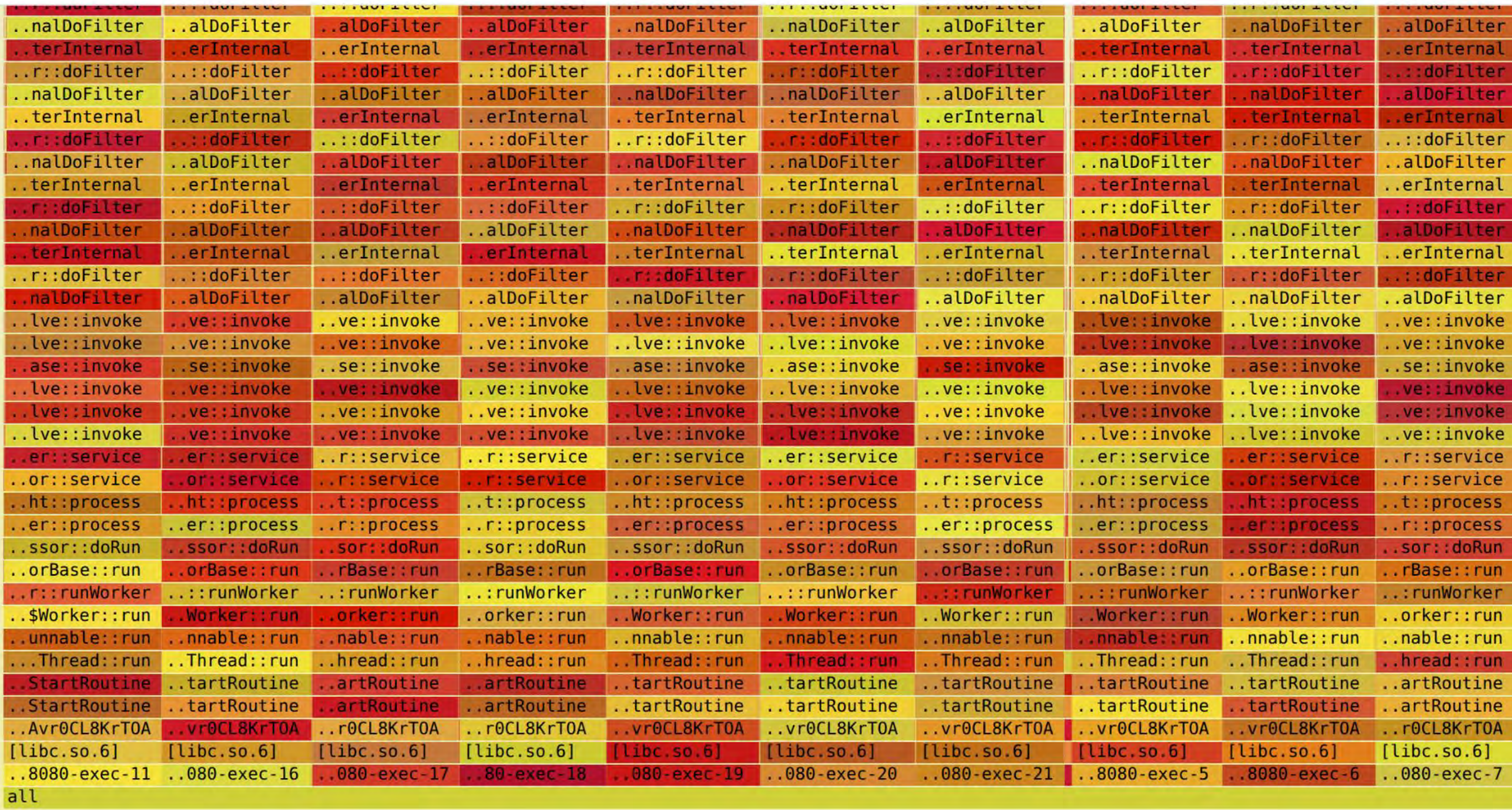
https://github.com/flamegraph-rs/flamegraph

```
$ sudo flamegraph -o stack-trace.svg -c "record -F 99 -g" --pid <host pid>
```



perf-map agent
is needed
for JVM

But not for
native image


..nalDoFilter ..alDoFilter ..alDoFilter ..alDoFilter ..nalDoFilter ..nalDoFilter ..alDoFilter ..alDoFilter ..nalDoFilter ..alDoFilter
..terInternal ..erInternal ..erInternal ..erInternal ..terInternal ..terInternal ..erInternal ..terInternal ..terInternal ..erInternal
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..nalDoFilter ..alDoFilter ..alDoFilter ..alDoFilter ..nalDoFilter ..nalDoFilter ..alDoFilter ..nalDoFilter ..nalDoFilter ..alDoFilter
..terInternal ..erInternal ..erInternal ..erInternal ..terInternal ..terInternal ..erInternal ..terInternal ..terInternal ..erInternal
..r::doFilter ..::doFilter ..::doFilter ..::doFilter ..r::doFilter ..r::doFilter ..::doFilter ..r::doFilter ..r::doFilter ..::doFilter
..nalDoFilter ..alDoFilter ..alDoFilter ..alDoFilter ..nalDoFilter ..nalDoFilter ..alDoFilter ..nalDoFilter ..nalDoFilter ..alDoFilter
..terInternal ..erInternal ..erInternal ..erInternal ..terInternal ..terInternal ..erInternal ..terInternal ..terInternal ..erInternal
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..lve::invoke ..ve::invoke ..ve::invoke ..ve::invoke ..lve::invoke ..lve::invoke ..ve::invoke ..lve::invoke ..lve::invoke ..ve::invoke
..er::service ..er::service ..r::service ..r::service ..er::service ..er::service ..r::service ..er::service ..er::service ..r::service
..or::service ..or::service ..r::service ..r::service ..or::service ..or::service ..r::service ..or::service ..or::service ..r::service
..ht::process ..ht::process ..t::process ..t::process ..ht::process ..ht::process ..t::process ..ht::process ..ht::process ..t::process
..er::process ..er::process ..r::process ..r::process ..er::process ..er::process ..er::process ..er::process ..er::process ..r::process
..ssor::doRun ..ssor::doRun ..sor::doRun ..sor::doRun ..ssor::doRun ..ssor::doRun ..ssor::doRun ..ssor::doRun ..ssor::doRun ..sor::doRun
..orBase::run ..orBase::run ..rBase::run ..rBase::run ..orBase::run ..orBase::run ..orBase::run ..orBase::run ..orBase::run ..rBase::run
..r::runWorker ..::runWorker ..:runWorker ..:runWorker ..::runWorker ..::runWorker ..::runWorker ..::runWorker ..::runWorker ..:runWorker
..$Worker::run ..Worker::run ..orker::run ..orker::run ..Worker::run ..Worker::run ..Worker::run ..Worker::run ..Worker::run ..orker::run
..unnable::run ..nnable::run ..nable::run ..nable::run ..nnable::run ..nnable::run ..nnable::run ..nnable::run ..nnable::run ..nable::run
...Thread::run ..Thread::run ..hread::run ..hread::run ..Thread::run ..Thread::run ..Thread::run ..Thread::run ..Thread::run ..hread::run
..StartRoutine ..tartRoutine ..artRoutine ..artRoutine ..tartRoutine ..tartRoutine ..tartRoutine ..tartRoutine ..tartRoutine ..artRoutine
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[libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6] [libc.so.6]
..8080-exec-11 ..080-exec-16 ..080-exec-17 ..80-exec-18 ..080-exec-19 ..080-exec-20 ..080-exec-21 ..8080-exec-5 ..8080-exec-6 ..080-exec-7
all


..ptor::invoke
..sion.SimpleExpression::executeSimple
void org.thymeleaf.engine.Model::process
..r::do
..ion::proceed
..ndard.expression.Expression::execute
..eaf.engine.IteratedGatheringModelProcessable::processIterationModel
..sor::
..ptor::invoke
..ndard.expression.Expression::execute
..ean org.thymeleaf.engine.IteratedGatheringModelProcessable::process
..per::
..ion::proceed
..essionAttributeTagProcessor::doProcess
..d org.thymeleaf.engine.ProcessorTemplateHandler::handleCloseElement
..leOpen
..nTransaction
..stractAttributeTagProcessor::doProcess
void org.thymeleaf.engine.CloseElementTag::beHandled
..ag::be
..ptor::invoke
..t.AbstractElementTagProcessor::process
void org.thymeleaf.engine.Model::process
..ion::proceed
..ls$ElementTagProcessorWrapper::process
void org.thymeleaf.engine.ProcessorTemplateHandler::handleOpenElement
..ptor::invoke
..ssorTemplateHandler::handleOpenElement
void org.thymeleaf.engine.OpenElementTag::beHandled
..ion::proceed
..eleaf.engine.OpenElementTag::beHandled
void org.thymeleaf.engine.Model::process
..ptor::invoke
void org.thymeleaf.engine.Model::process
boolean org.thymeleaf.engine.GatheringModelProcessable::process
..ion::proceed
..essorTemplateHandler::handleOpenElement
void org.thymeleaf.engine.ProcessorTemplateHandler::handleStandaloneElement
..roxy::invoke
..meleaf.engine.OpenElementTag::beHandled
void org.thymeleaf.engine.StandaloneElementTag::beHandled
..StartingWith
void org.thymeleaf.engine.Model::process
..nersLastName
void org.thymeleaf.engine.ProcessorTemplateHandler::handleOpenElement
..cessFindForm
void org.thymeleaf.engine.OpenElementTag::beHandled
..C58wtqRibjMF
void org.thymeleaf.engine.TemplateModel::process
..ssor::invoke
void org.thymeleaf.engine.TemplateManager::parseAndProcess
..od::doInvoke
void org.thymeleaf.TemplateEngine::process
..okeForRequest
void org.thymeleaf.TemplateEngine::process
..vokeAndHandle
void org.thymeleaf.spring6.view.ThymeleafView::renderFragment
..vokeHandlerMethod
void org.thymeleaf.spring6.view.ThymeleafView::render
..r::handleInternal
void org.springframework.web.servlet.DispatcherServlet::render
..odAdapter::handle
void org.springframework.web.servlet.DispatcherServlet::processDispatchResult
void org.springframework.web.servlet.DispatcherServlet::doDispatch
void org.springframework.web.servlet.DispatcherServlet::doService
void org.springframework.web.servlet.FrameworkServlet::processRequest
void jakarta.servlet.http.HttpServlet::service
void org.springframework.web.servlet.FrameworkServlet::service
void jakarta.servlet.http.HttpServlet::service
void org.apache.catalina.core.ApplicationFilterChain::internalDoFilter
void org.apache.tomcat.websocket.server.WsFilter::doFilter
void org.apache.catalina.core.ApplicationFilterChain::internalDoFilter
void org.springframework.web.servlet.resource.ResourceUrlEncodingFilter::doFilter
void org.apache.catalina.core.ApplicationFilterChain::internalDoFilter
void org.springframework.web.filter.RequestContextFilter::doFilterInternal
void org.springframework.web.filter.OncePerRequestFilter::doFilter
void org.apache.catalina.core.ApplicationFilterChain::internalDoFilter
void org.springframework.web.filter.FormContentFilter::doFilterInternal

Conclusions

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Try at home

- Refer the documentation at graalvm.org
- Profiling theory & practice
- Platform tools may need baking target
- Java tools may need that too
- Java tools may work differently
- There are many limitations

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Thank you for your attention!

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Q & A