JVMs.Compare

Benchmark Performance of Different JDK/JVM combos

Chandra Guntur & Donald Raab

@CGuntur @TheDonRaab

About Us

- Java Champions
- JCP Executive Committee Reps. for BNY Mellon
- Ardent bloggers and tweeters

- Director at BNY Mellon
- Working in Financial Tech. since 2003
- Programming in Java since 1998
- JUG Leader @ NYJavaSIG
- Creator of Java-Katas Github repository

- Managing Director at BNY Mellon
- 18+ years of experience in Financial Tech.
- Programming in Java since 1997
- Member of JSR 335 Expert Group
- Creator of Eclipse Collection Java Library

Session Agenda

Compare benchmarks for operations using

Eclipse Collections and JDK's Java Collection Framework:

- on a primitive IntList & List<Integer>
- on a List<Person>

using several JDK/JVM combinations

Compared JDK/JVMs

JDK/JVM combinations tested:

1. Oracle JDK 8 (v1.8.0_221)
2. GraalVM Enterprise Edition (v19.2.0)
3. GraalVM Community Edition (v19.2.0)
4. AdoptOpenJDK 8 w/Hotspot (v1.8.0_221)
5. AdoptOpenJDK 8 w/OpenJ9 (v1.8.0_221)
6. OpenJDK 11 (v11.0.2)
7. OpenJDK 11 embedded Graal JVMCI (v11.0.2)
8. GraalVM Enterprise Edition C2 Compiler (v19.2.0)

Benchmarks on IntList operations

Three operations were benchmarked on primitive collections:

- Filter: Filter in all even numbers (5 benchmarks)
- Sum: Sum of all integers in the collection (5 benchmarks)
- Transform: Multiply each integer by 2 (5 benchmarks)

Benchmarks on Object operations

Four operations were benchmarked on non-primitive collections:

- Filter: Filter all Persons with height between 80 and 150 inches (7 benchmarks)
- FilterAndGroup: Filter all Persons less than 150 inches tall, then group by age (7 benchmarks)
- IntSummaryStatistics: Summary statistics by age (integer) of all Person instances (5 benchmarks)
- CombinedSummaryStatistics: Summary statistics on height (double), weight (double) and age (integer) (5 benchmarks)

JDK Flags - Part 1

In order to run the embedded Graal compiler in OpenJDK 11:

- +XX:+UnlockExperimentalVMOptions
- +XX:+EnableJVMCI
- +XX:+UseJVMCICompiler

JDK Flags - Part 2

In order to run the C2 compiler in GraalVM EE v19.2.0:

- +XX:+UnlockExperimentalVMOptions
- +XX:-UseJVMCICompiler

Notice the minus before the UseJVMCICompiler

Hardware - The Beast

Model Name: Mac Pro
Model Identifier: MacPro6,1
Processor Name: 12-Core Intel Xeon E5
Processor Speed: 2.7 GHz
Number of Processors: 1
Total Number of Cores: 12
L2 Cache (per Core): 256 KB
L3 Cache: 30 MB
Memory: 64 GB

Hardware - The Little Monster

Model Name: MacBook Pro
Model Identifier: MacBookPro11,1
Processor Name: Intel Core i7
Processor Speed: 2.8 GHz
Number of Processors: 1
Total Number of Cores: 2
L2 Cache (per Core): 256 KB
L3 Cache: 4 MB
Memory: 16 GB

Benchmark Math

Some relevant numbers in terms of what was run:

- 7 Benchmark classes
- 8 JDK/JVM combinations
- 2 runs
  - Mode.Throughput on collections, seeded with size = 1_000_000
  - Mode.Throughput on collections, seeded with size = 1000
- 39 benchmarks in the 7 classes = 2184 benchmarks.
- Executed twice = 4368 total benchmarks.
- Throughput benchmarks - higher is better.

HANDS ON !

Benchmark Source:

https://github.com/c-guntur/jvms-compare

Benchmark Visualization:

https://jmh.morethan.io

How to read the graphs

JMH Visualizer
jmh.morethan.io
JMH Visualizer
01_OracleJDK8IntListFilter
02_GraalEEIntListFilter
03_GraalCEIntListFilter
04_AdoptOpenJDK8HotspotIntListFilter
05_AdoptOpenJDKOpenJ9IntListFilter
06_OpenJDK11HotspotIntListFilter
07_OpenJDK11GraalIntListFilter
08_GraalEEC2IntListFilter
Compare
Comparing 1 benchmark classes for 8 runs on metric 'Score'.
IntListFilter
Throughput
Each line = @Benchmark
Y-axis = Throughput
Benchmarks
IntListFilter
Throughput
900
600
300
0
0
X-axis = JDK/JVMs
filterEC
filterECParallel
filterECPrimitive
filterJDKBoxed
filterJDKBoxedParallel
JVM/JDK

Collection Size 1M

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8IntListFilter | 02_GraalEEIntListFilter | 03_GraalCEIntListFilter | 04_AdoptOpenJDK8HotspotIntListFilter | 05_AdoptOpenJDKOpenJ9IntListFilter | 06_OpenJDK11HotspotIntListFilter | 07_OpenJDK11GraalIntListFilter | 08_GraalEEC2IntListFilter

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

IntListFilter Throughput

Score

Benchmarks

IntListFilter

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8IntListTransform | 02_GraalEEIntListTransform | 03_GraalCEIntListTransform | 04_AdoptOpenJDK8HotspotIntListTransform

05_AdoptOpenJDKOpenJ9IntListTransform | 06_OpenJDK11HotspotIntListTransform | 07_OpenJDK11GraalIntListTransform | 08_GraalEEC2IntListTransform

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

IntListTransform Throughput

Benchmarks

IntListTransform

01 = Oracle JDK 8

02 = GraalEE 19.2.0

03 = Graal Community 19.2.0

04 = AdoptOpenJDK8 Hotspot

05 = AdoptOpenJDK8 OpenJ9

06 = OpenJDK 11 Hotspot

07 = OpenJDK 11 Graal JVMCI

08 = Graal Embedded Hotspot

Collection Size 1K

Collection Size 1M

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonFilter | 02_GraalEEPersonFilter | 03_GraalCEPersonFilter | 04_AdoptOpenJDK8HotspotPersonFilter | 05_AdoptOpenJDKOpenJ9PersonFilter | 06_OpenJDK11HotspotPersonFilter | 07_OpenJDK11GraalPersonFilter | 08_GraalEEC2PersonFilter

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonFilterOnly Throughput

Benchmarks

PersonFilterOnly

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonFilter | 02_GraalEEPersonFilter | 03_GraalCEPersonFilter | 04_AdoptOpenJDK8HotspotPersonFilter

05_AdoptOpenJDKOpenJ9PersonFilter | 06_OpenJDK11HotspotPersonFilter | 07_OpenJDK11GraalPersonFilter | 08_GraalEEC2PersonFilter

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonFilterOnly Throughput

Benchmarks

PersonFilterOnly

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonFilterAndGroup | 02_GraalEEPersonFilterAndGroup | 03_GraalCEPersonFilterAndGroup | 04_AdoptOpenJDK8HotspotPersonFilterAndGroup | 05_AdoptOpenJDKOpenJ9PersonFilterAndGroup | 06_OpenJDK11HotspotPersonFilterAndGroup | 07_OpenJDK11GraalPersonFilterAndGroup | 08_GraalEEC2PersonFilterAndGroup

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonFilterAndGroup Throughput

Benchmarks

PersonFilterAndGroup

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonFilterAndGroup | 02_GraalEEPersonFilterAndGroup | 03_GraalCEPersonFilterAndGroup

04_AdoptOpenJDK8HotspotPersonFilterAndGroup | 05_AdoptOpenJDKOpenJ9PersonFilterAndGroup | 06_OpenJDK11HotspotPersonFilterAndGroup

07_OpenJDK11GraalPersonFilterAndGroup | 08_GraalEEC2PersonFilterAndGroup

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonFilterAndGroup Throughput

Benchmarks

PersonFilterAndGroup

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonIntSummaryStats | 02_GraalEEPersonIntSummaryStats | 03_GraalCEPersonIntSummaryStats
04_AdoptOpenJDK8HotspotPersonIntSummaryStats | 05_AdoptOpenJDKOpenJ9PersonIntSummaryStats | 06_OpenJDK11HotspotPersonIntSummaryStats
07_OpenJDK11GraalPersonIntSummaryStats | 08_GraalEEC2PersonIntSummaryStats

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonIntSummaryStats Throughput

Benchmarks
PersonIntSummaryStats

01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot

01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot

Collection Size 1K

Collection Size 1M

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonCombinedSummaryStats | 02_GraalEEPersonCombinedSummaryStats | 03_GraalCEPersonCombinedSummaryStats

04_AdoptOpenJDK8HotspotPersonCombinedSummaryStats | 05_AdoptOpenJDKOpenJ9PersonCombinedSummaryStats

06_OpenJDK11HotspotPersonCombinedSummaryStats | 07_OpenJDK11GraalPersonCombinedSummaryStats | 08_GraalEEC2PersonCombinedSummaryStats

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonCombinedSummaryStats Throughput

Benchmarks

PersonCombinedSummary

01 = Oracle JDK 8

02 = GraalEE 19.2.0

03 = Graal Community 19.2.0

04 = AdoptOpenJDK8 Hotspot

05 = AdoptOpenJDK8 OpenJ9

06 = OpenJDK 11 Hotspot

07 = OpenJDK 11 Graal JVMCI

08 = Graal Embedded Hotspot

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8PersonCombinedSummaryStats | 02_GraalEEPersonCombinedSummaryStats | 03_GraalCEPersonCombinedSummaryStats

04_AdoptOpenJDK8HotspotPersonCombinedSummaryStats | 05_AdoptOpenJDKOpenJ9PersonCombinedSummaryStats

06_OpenJDK11HotspotPersonCombinedSummaryStats | 07_OpenJDK11GraalPersonCombinedSummaryStats | 08_GraalEEC2PersonCombinedSummaryStats

Compare

Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

PersonCombinedSummaryStats Throughput

Benchmarks

PersonCombinedSummary

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K