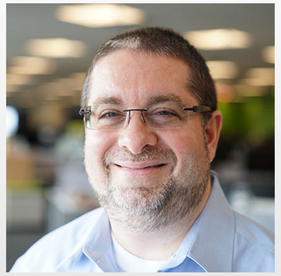
JVMs.Compare

Benchmark Performance of Different JDK/JVM combos

Chandra Guntur & Donald Raab

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:

Benchmarks on IntList operations

Three operations were benchmarked on primitive collections:

- Filter: Filter in all even numbers (5 benchmarks)

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)

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:

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)

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)

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)

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:

Benchmark Math

Some relevant numbers in terms of what was run:

- 7 Benchmark classes

Benchmark Math

Some relevant numbers in terms of what was run:

- 7 Benchmark classes
- 8 JDK/JVM combinations

Benchmark Math

Some relevant numbers in terms of what was run:

- 7 Benchmark classes
- 8 JDK/JVM combinations
- 2 runs

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

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

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.

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.

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.

Benchmark Math

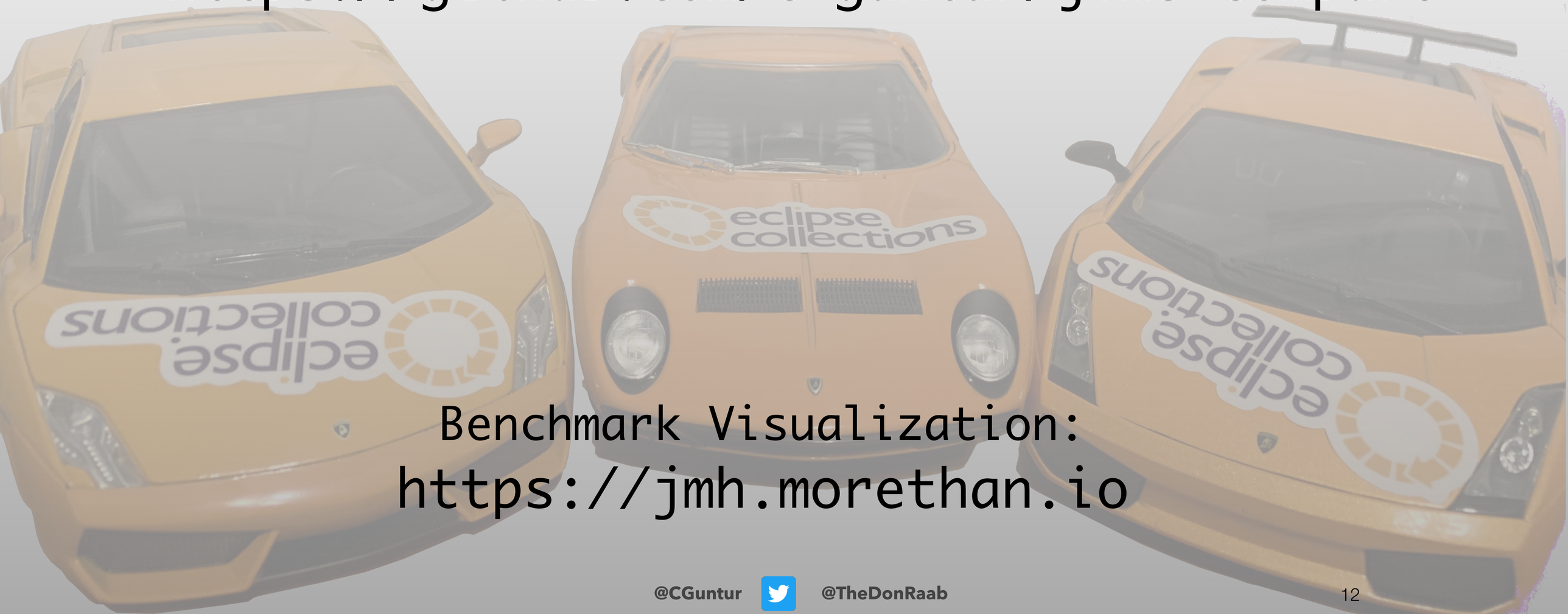
Some relevant numbers in terms of what was run:

- 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

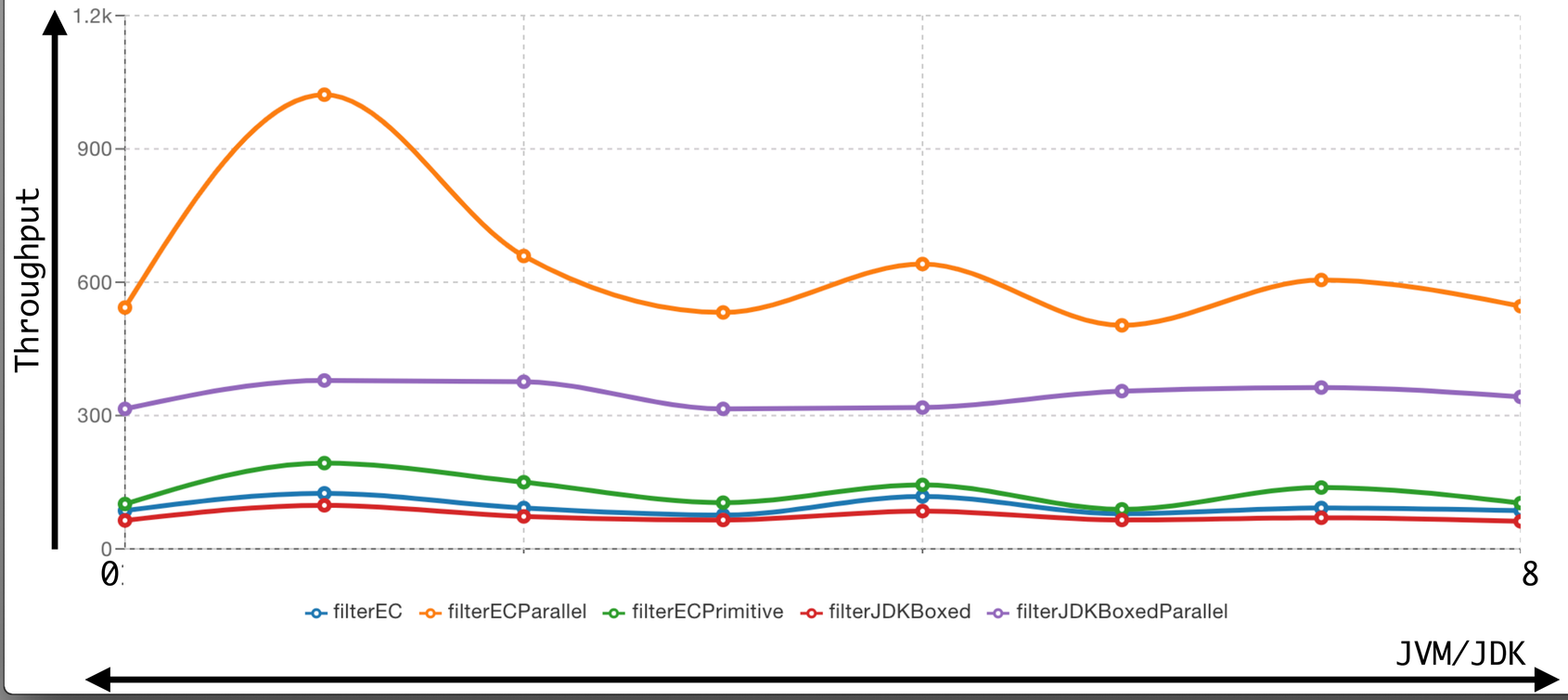
06_OpenJDK11HotspotIntListFilter | 07_OpenJDK11GraalIntListFilter | 08_GraalEEC2IntListFilter

Compare

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

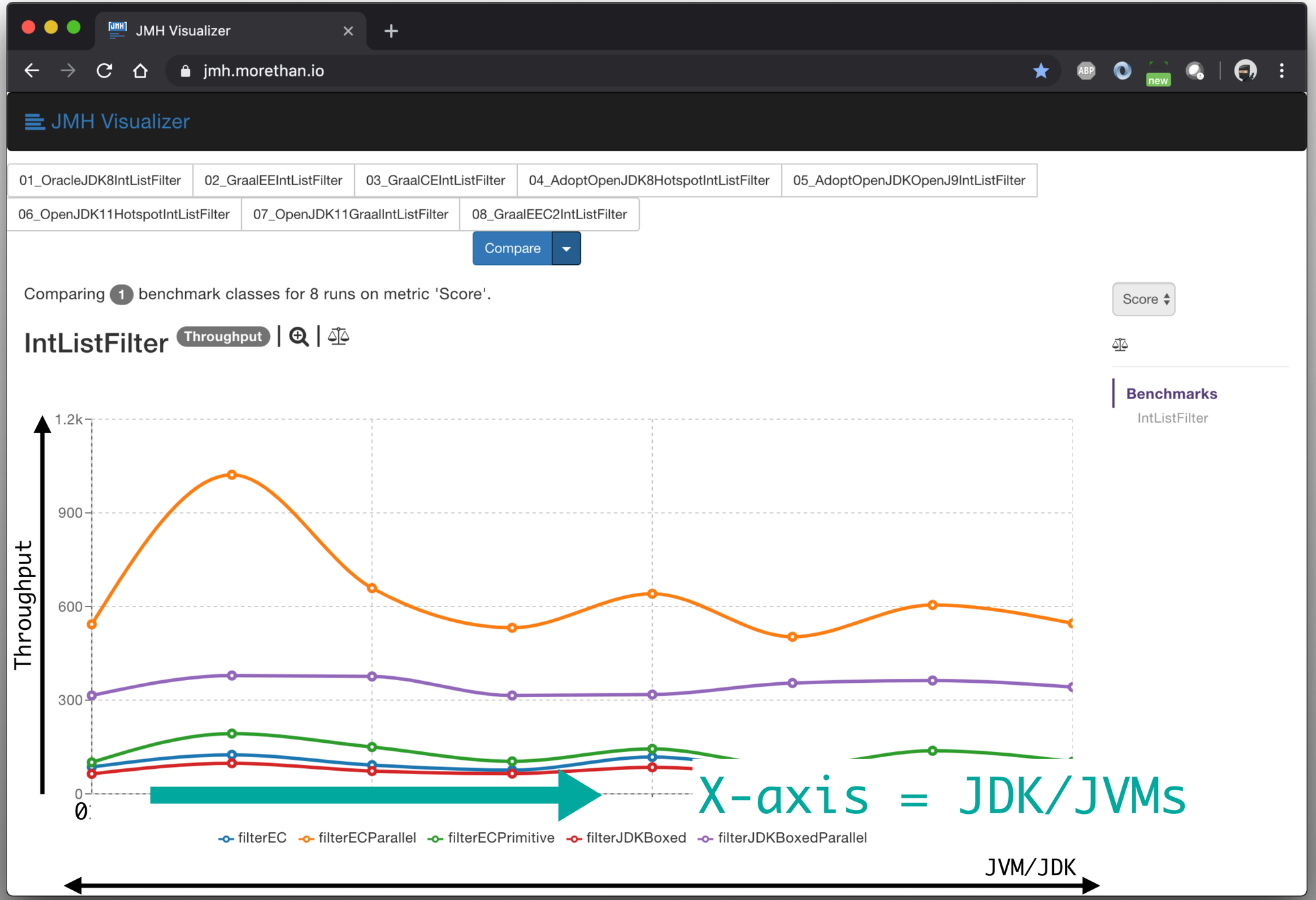
Score

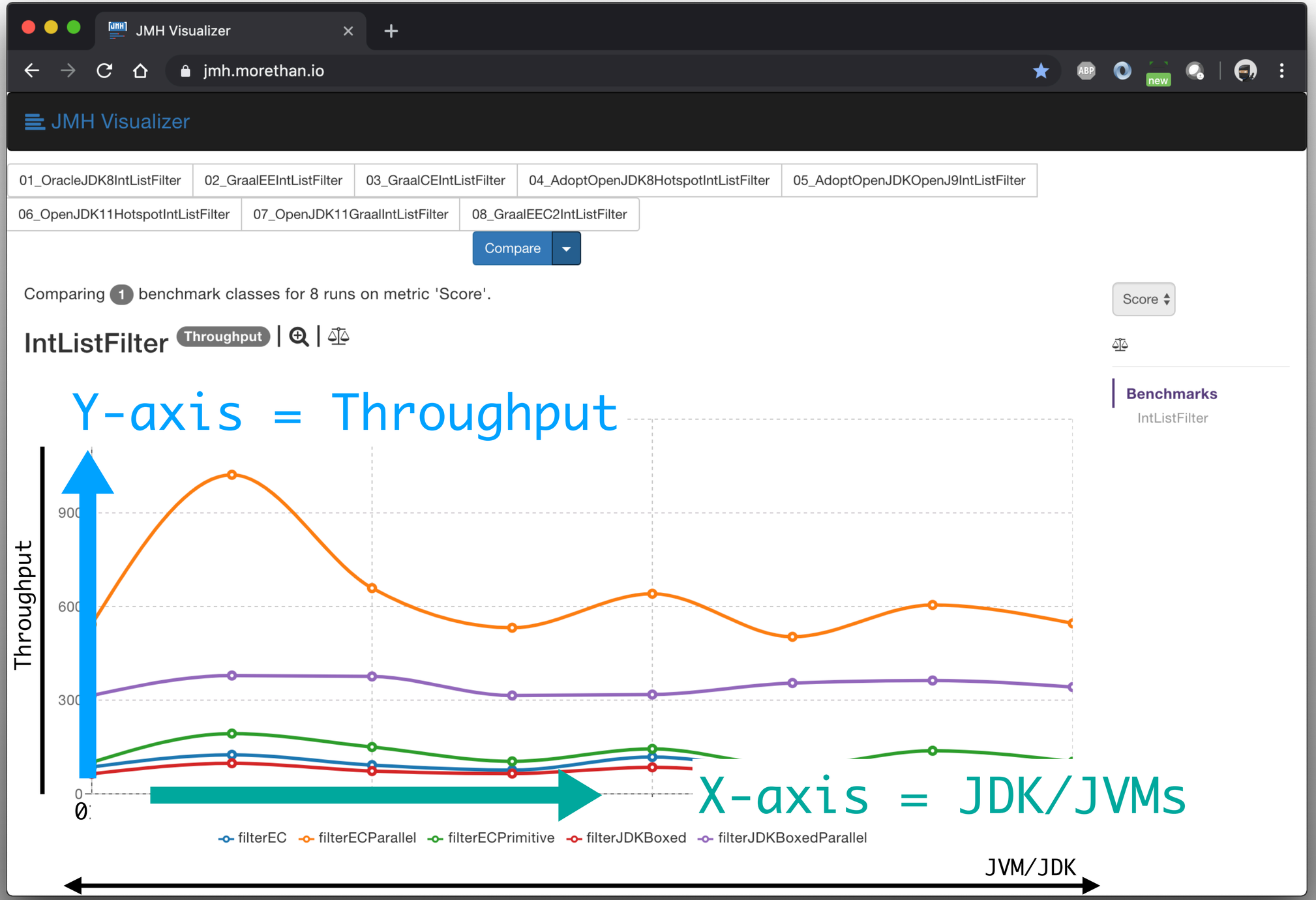
IntListFilter Throughput

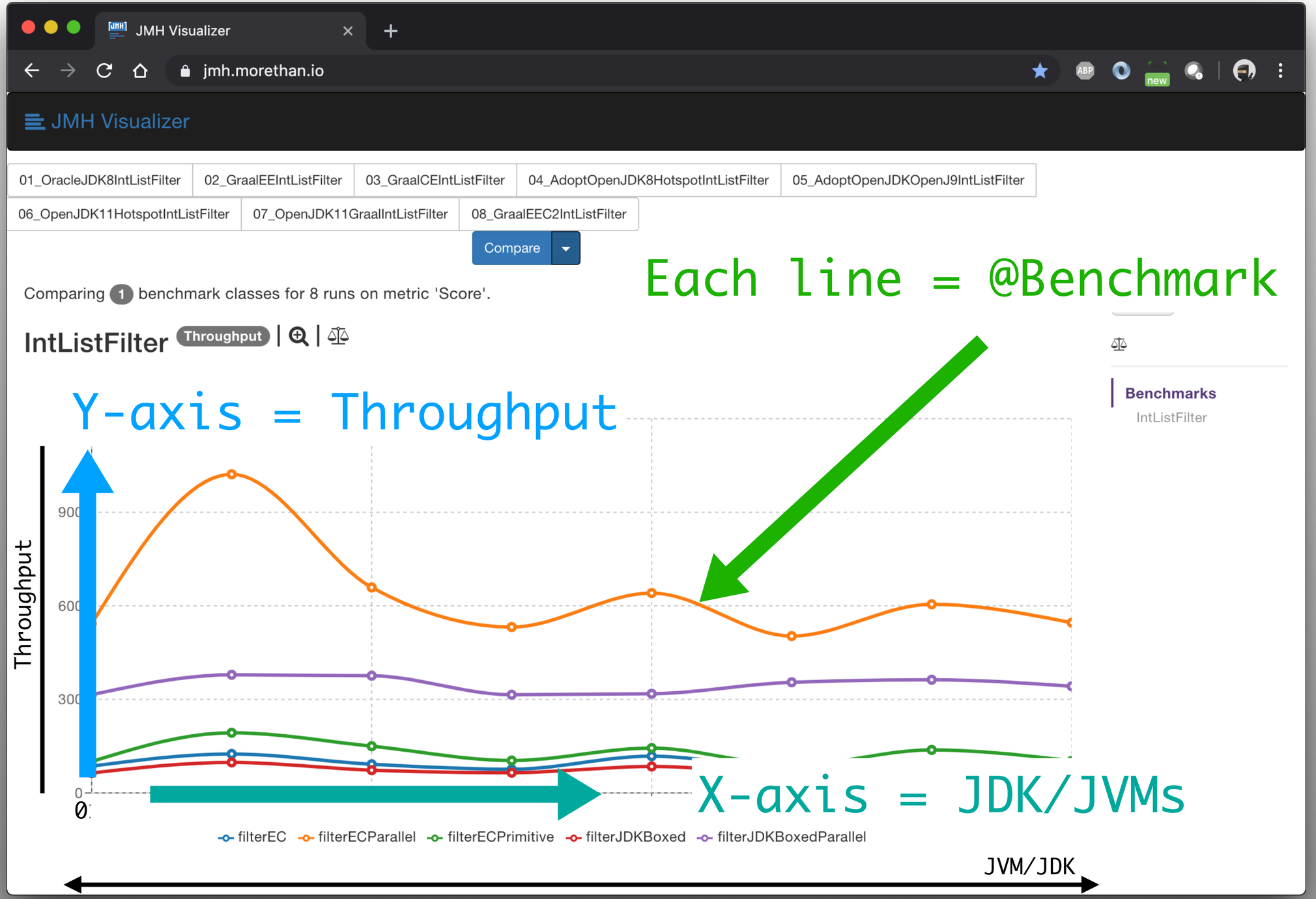


Benchmarks

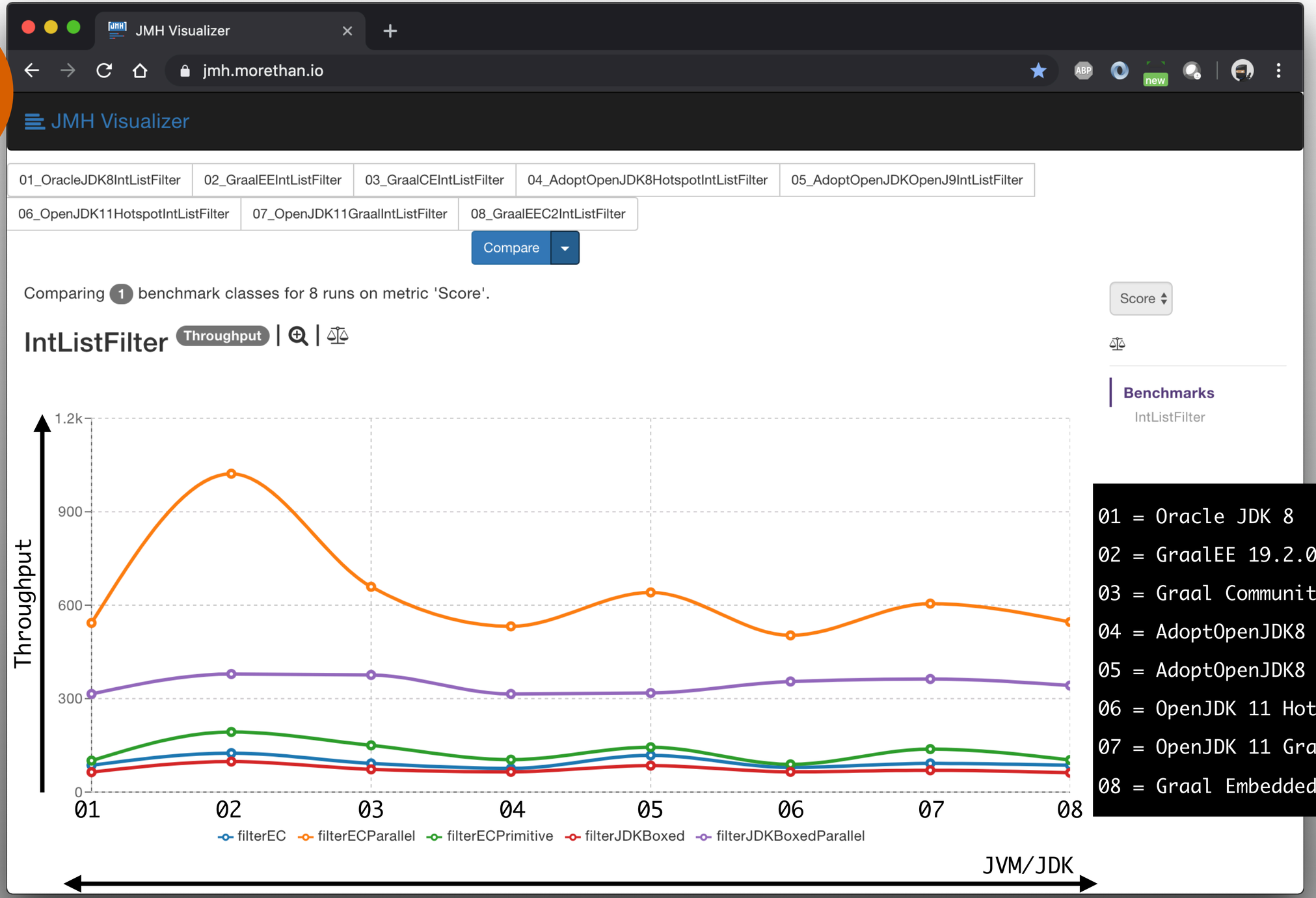
IntListFilter


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
1.2k
900
600
300
0
Throughput
X-axis = JDK/JVMs
filterEC
filterECParallel
filterECPrimitive
filterJDKBoxed
filterJDKBoxedParallel
JVM/JDK

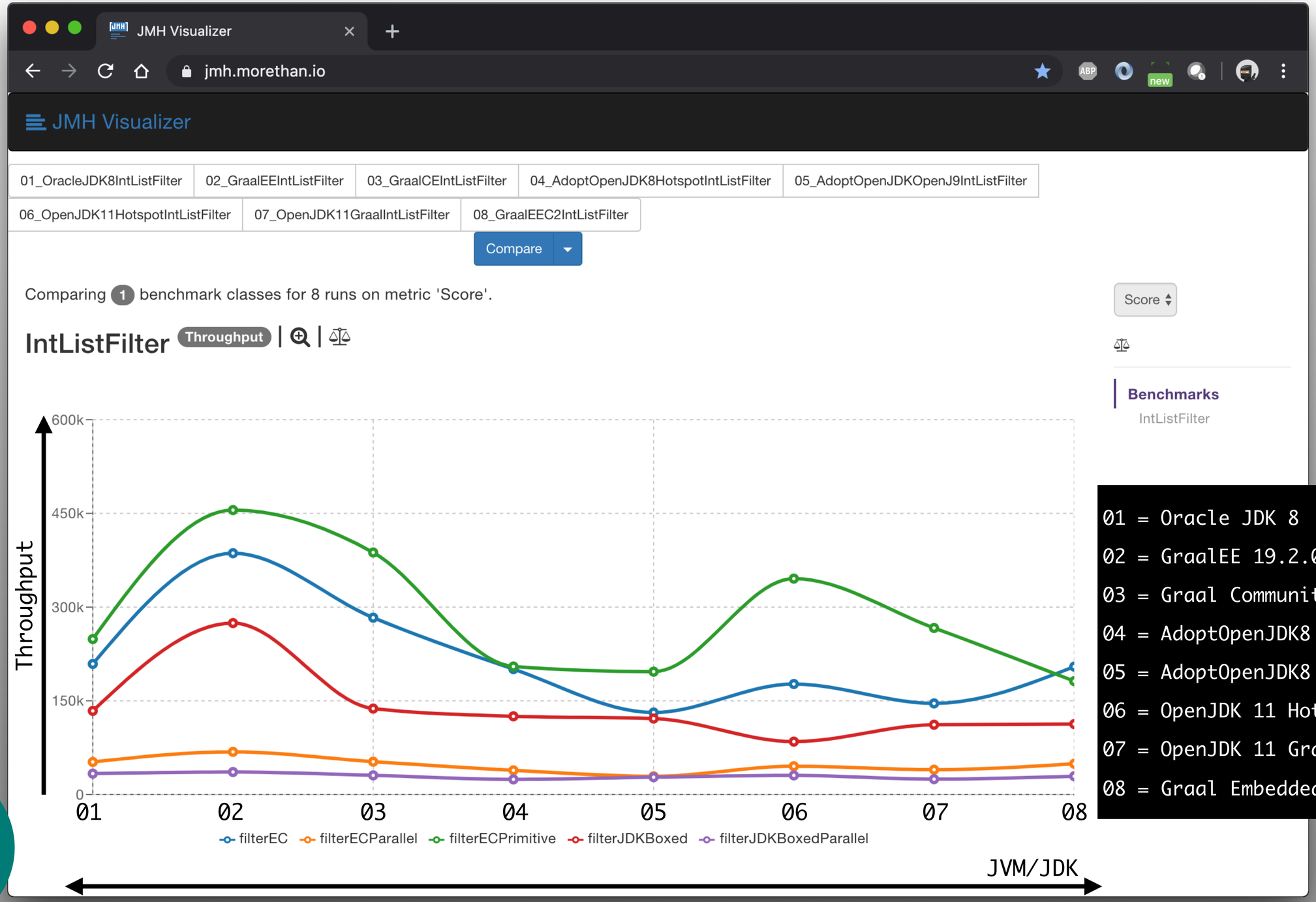

JMH Visualizer
jmh.morethan.io
JMH Visualizer
01_OracleJDK8IntListFilter
02_GraalEEIntListFilter
03_GraalCEIntListFilter
04_AdoptOpenJDK8HotspotIntListFilter
05_AdoptOpenJDKOpenJ9IntListFilter
06_OpenJDK11HotspotIntListFilter
07_OpenJDK11GraalIntListFilter
08_GraalEEC2IntListFilter
Compare
Comparing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


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

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

JMH Visualizer

jmh.morethan.io

JMH Visualizer

01_OracleJDK8IntListSum | 02_GraalEEIntListSum | 03_GraalCEIntListSum | 04_AdoptOpenJDK8HotspotIntListSum | 05_AdoptOpenJDKOpenJ9IntListSum

06_OpenJDK11HotspotIntListSum | 07_OpenJDK11GraalIntListSum | 08_GraalEEC2IntListSum

Compare

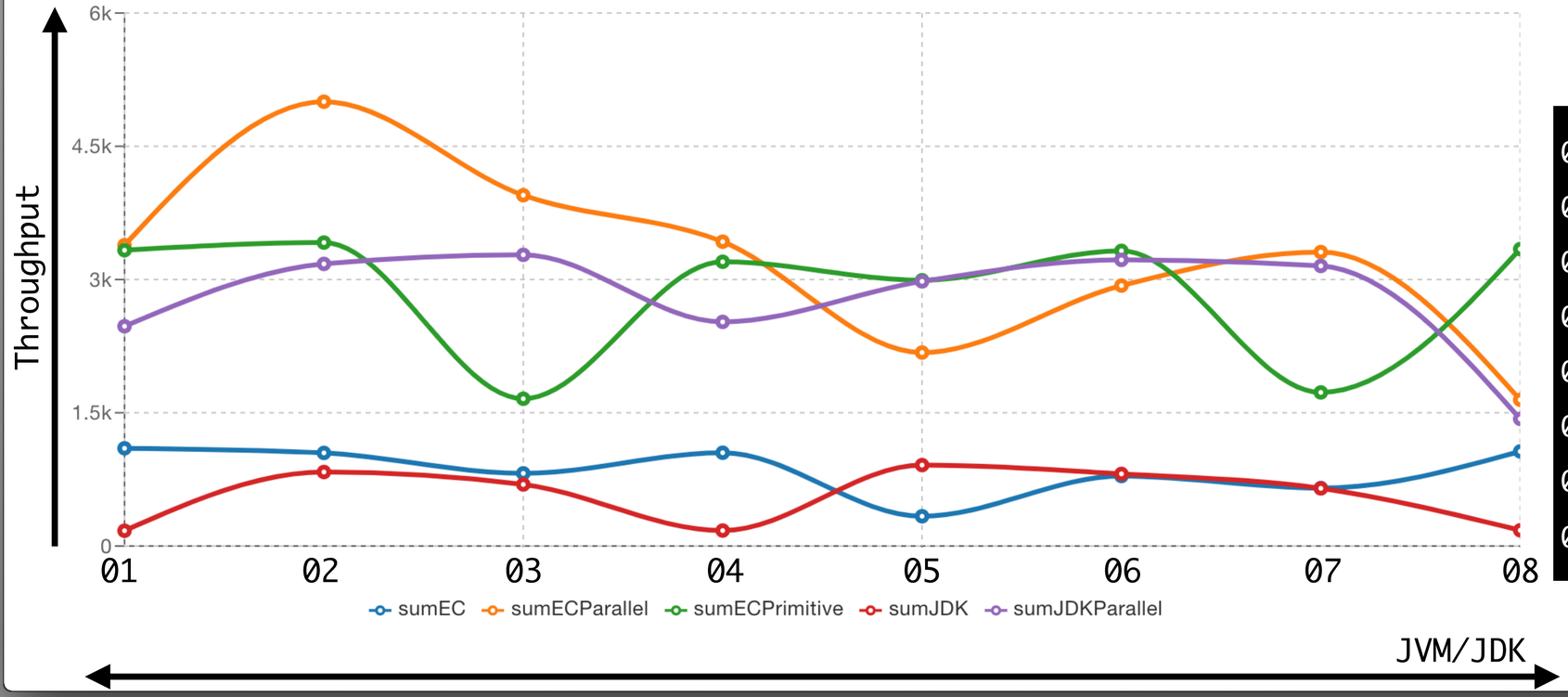
Comparing 1 benchmark classes for 8 runs on metric 'Score'.

Score

IntListSum Throughput

Benchmarks

IntListSum



01 = Oracle JDK 8

02 = GraalEE 19.2.0

03 = Graal Community 19.2.0

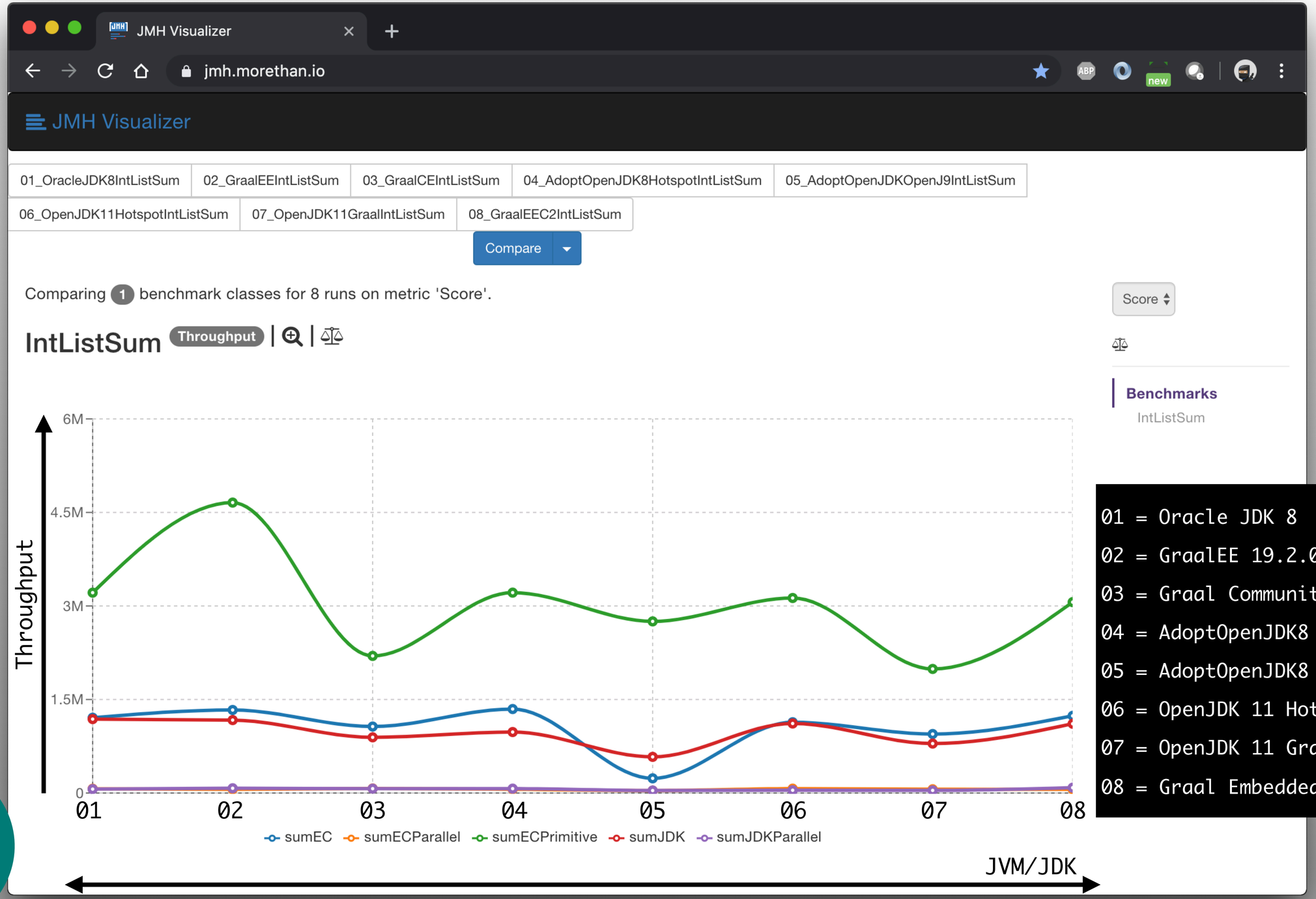
04 = AdoptOpenJDK8 Hotspot

05 = AdoptOpenJDK8 OpenJ9

06 = OpenJDK 11 Hotspot

07 = OpenJDK 11 Graal JVMCI

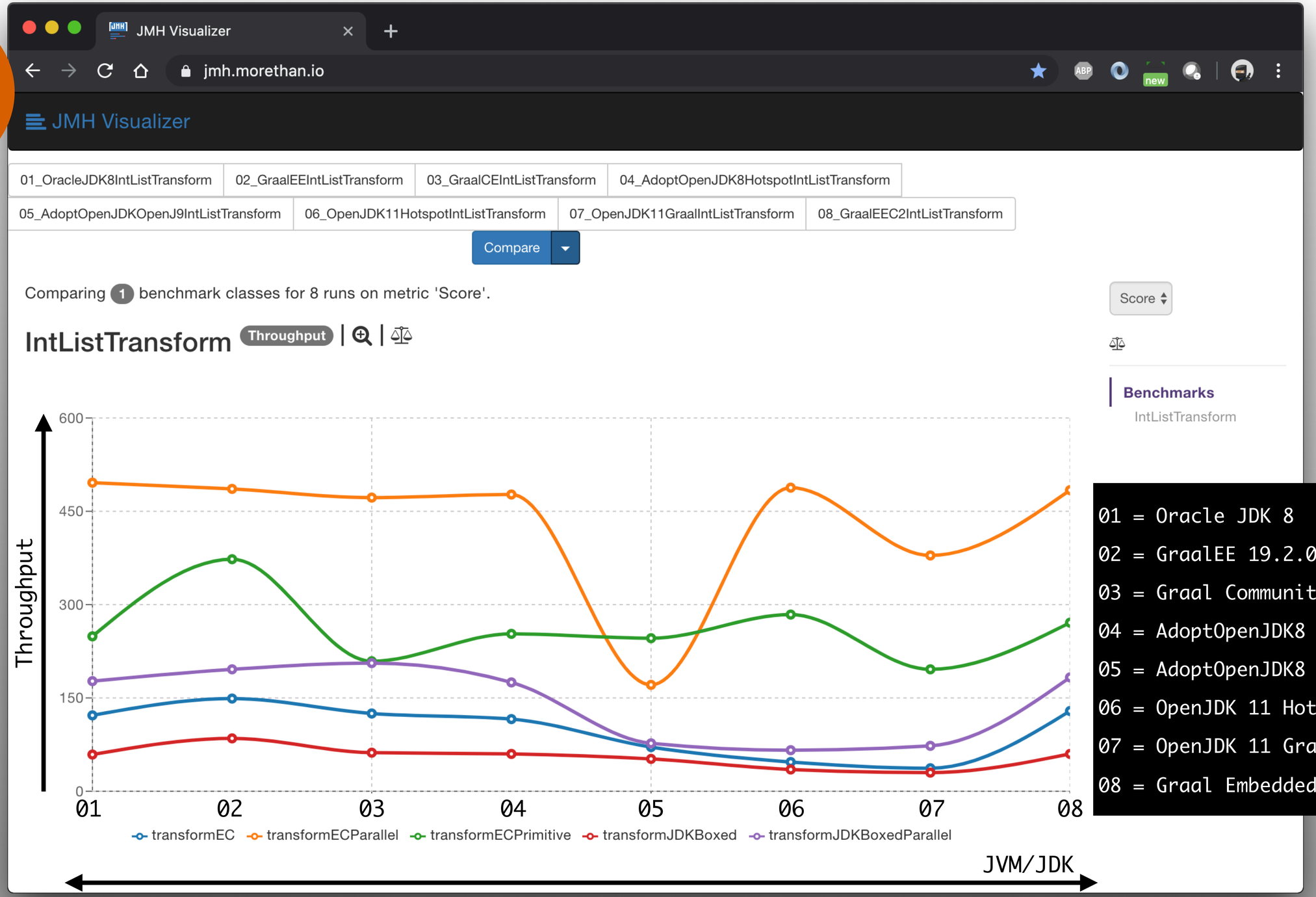
08 = Graal Embedded Hotspot



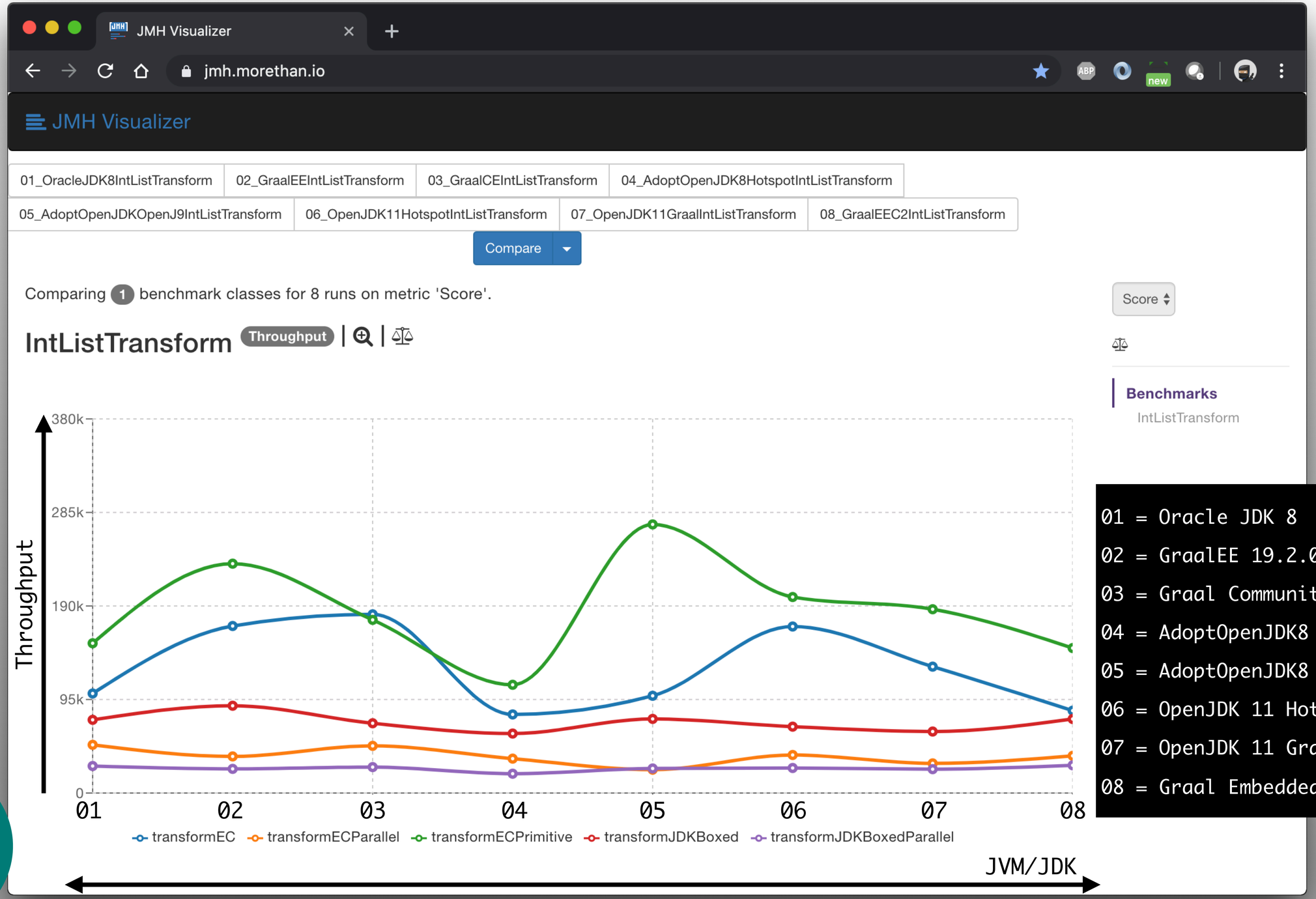

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M



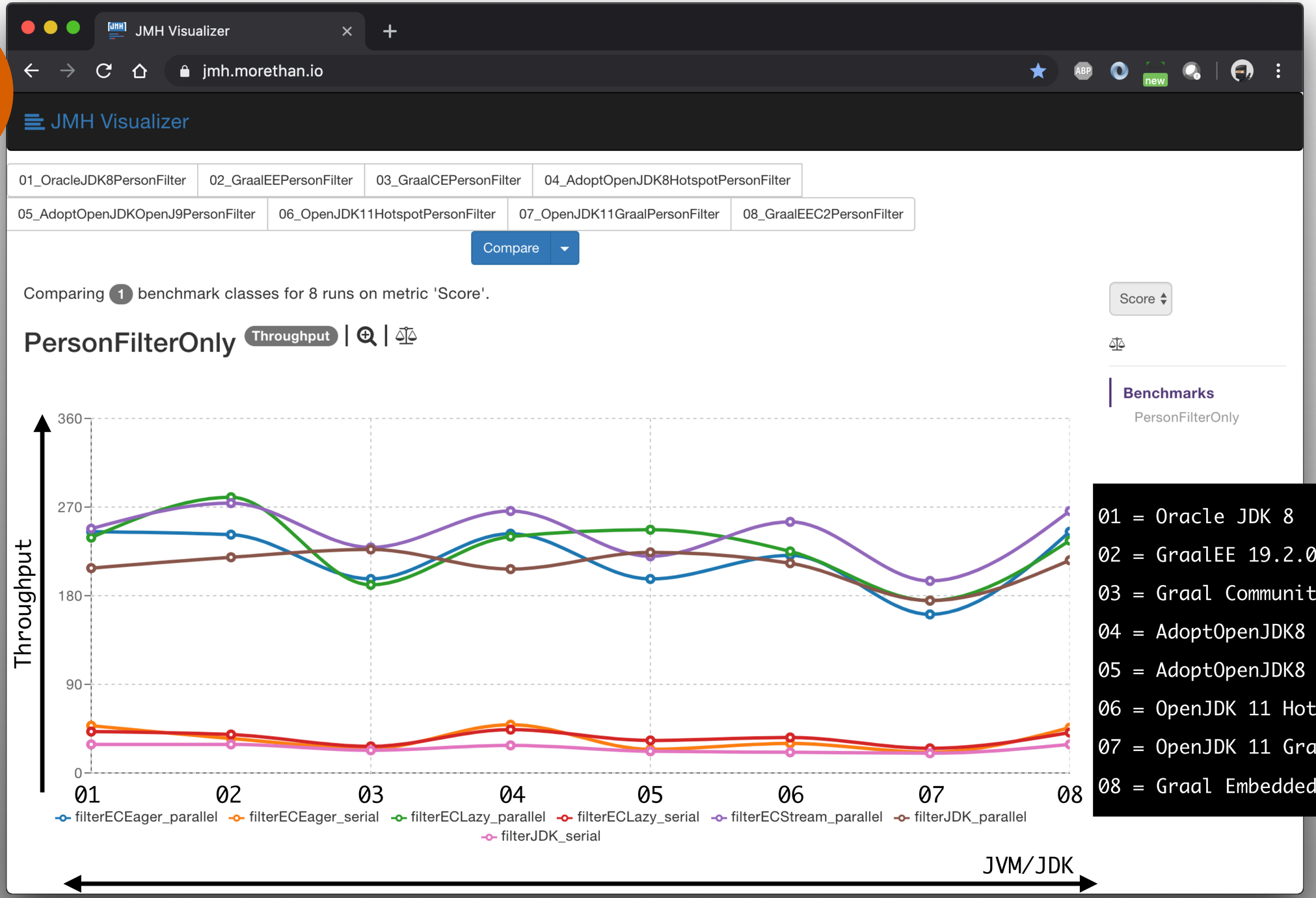

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```



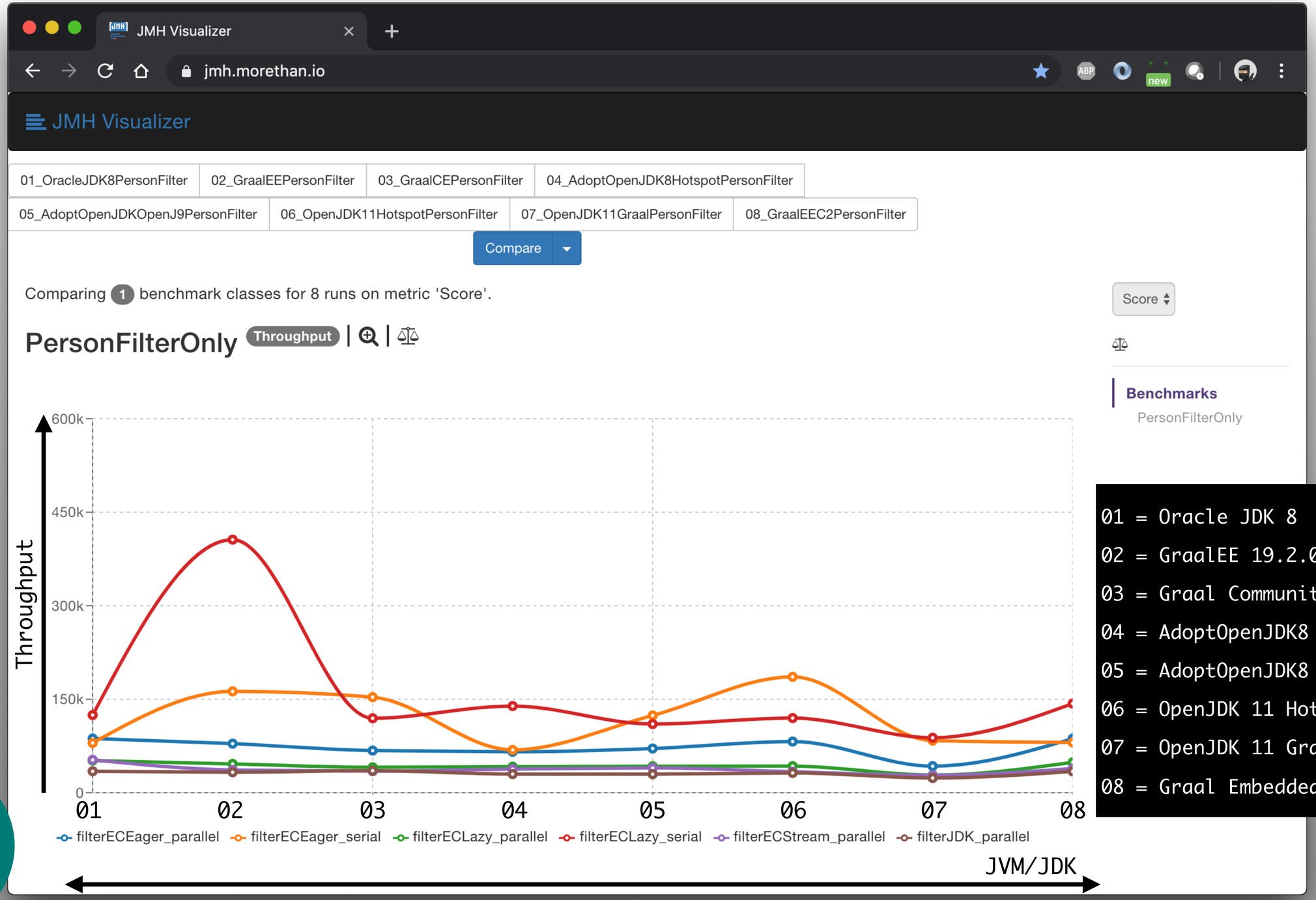

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M



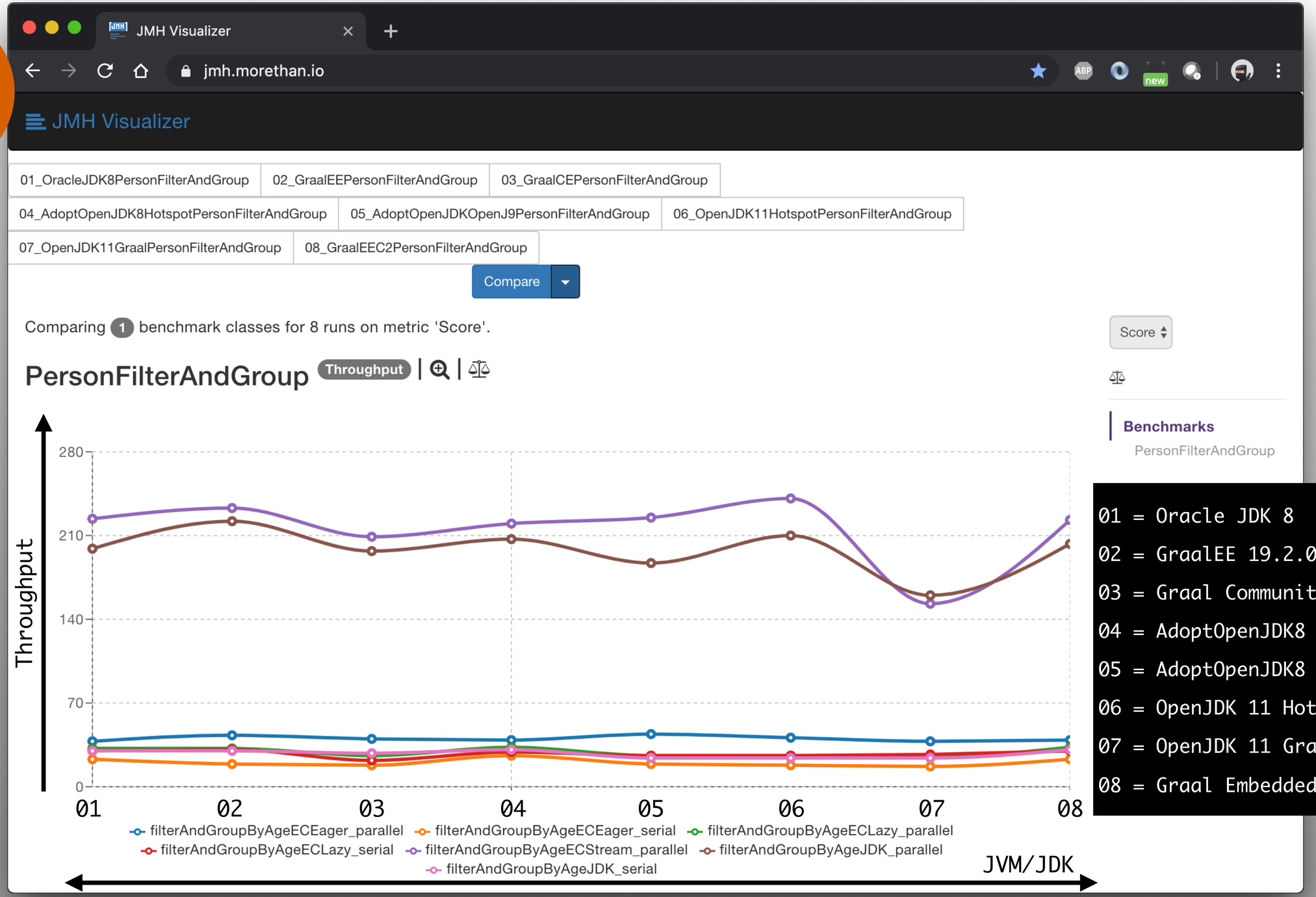

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```



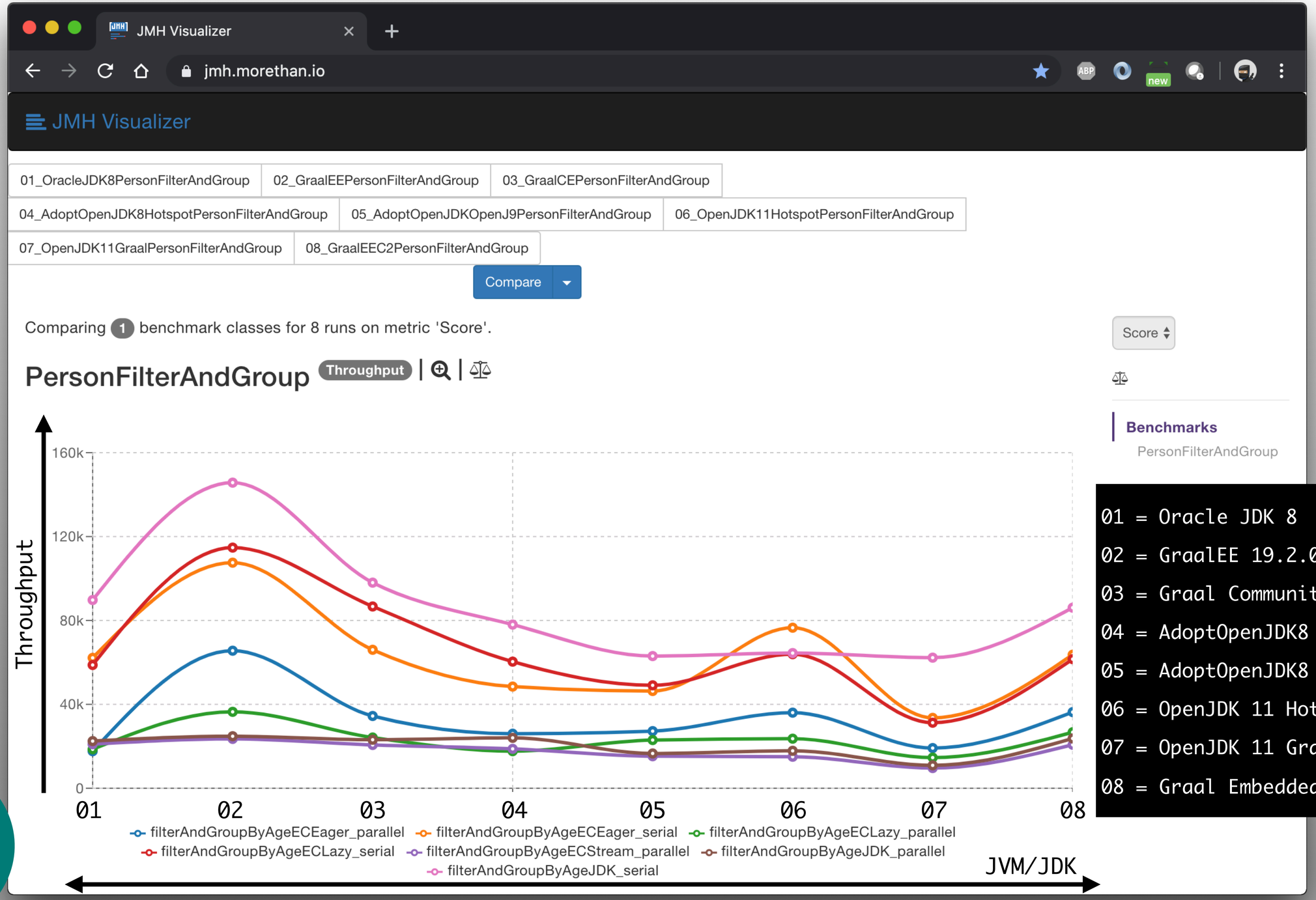

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M



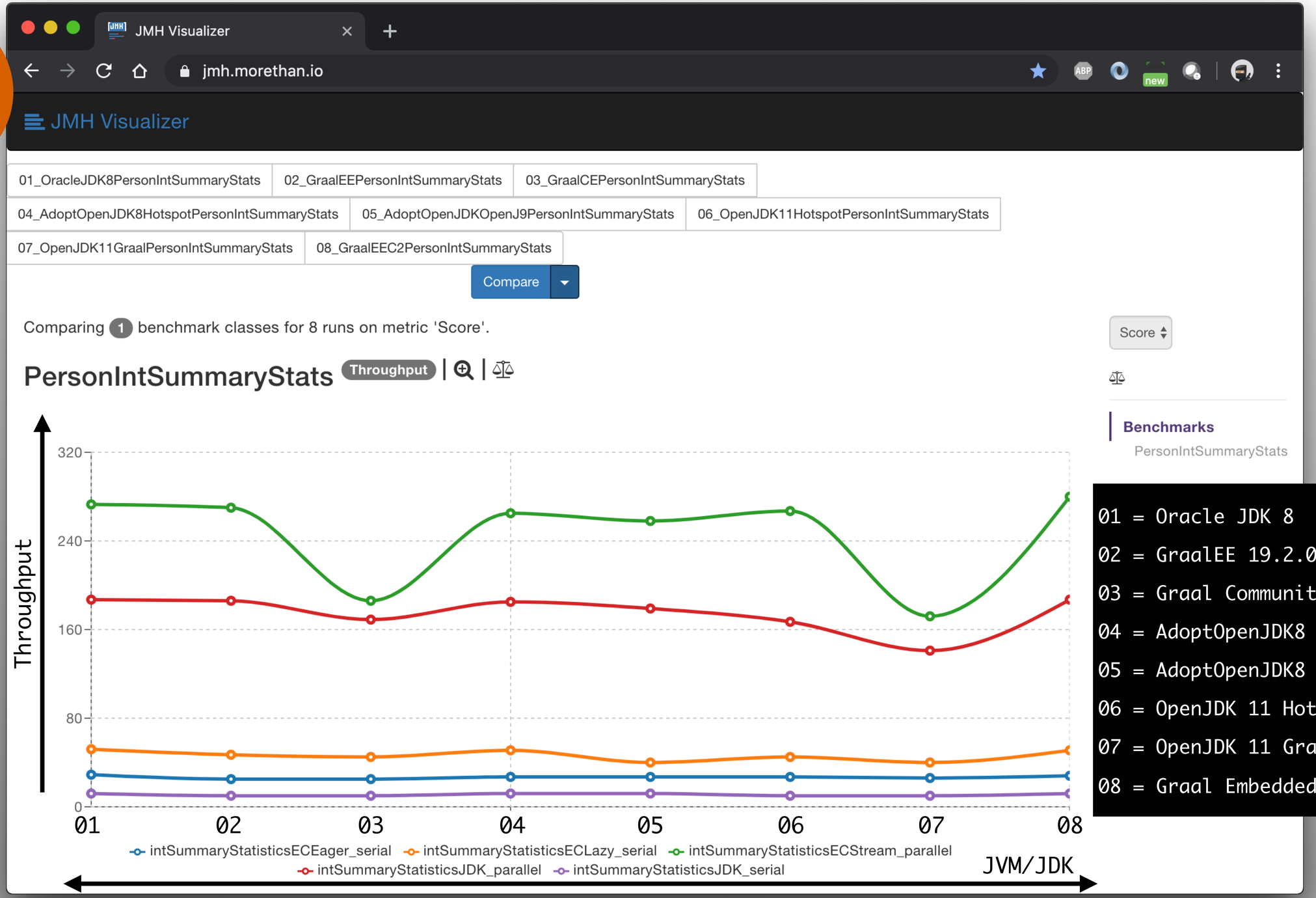

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```



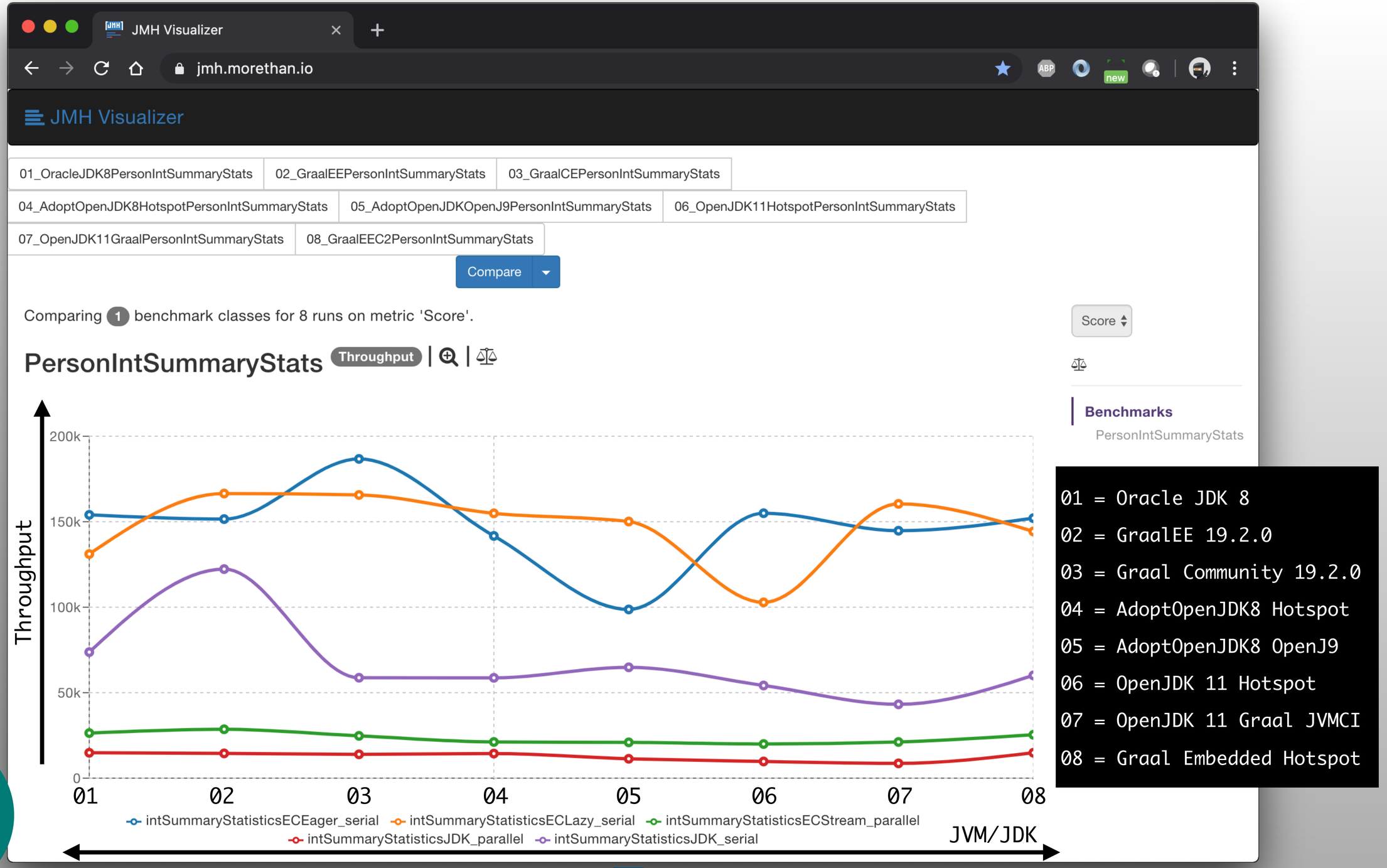

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

Collection Size 1K

Collection Size 1M



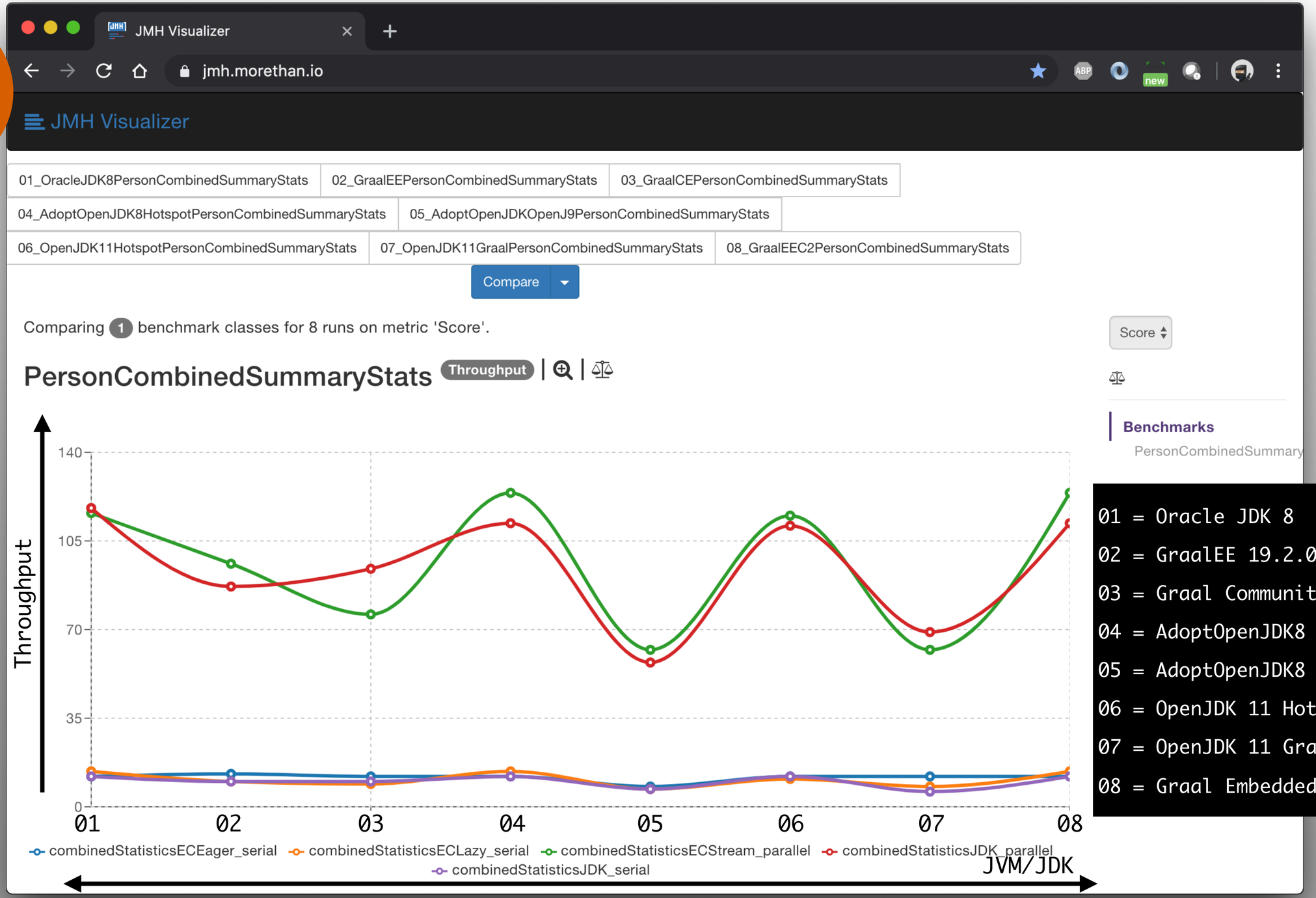

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```



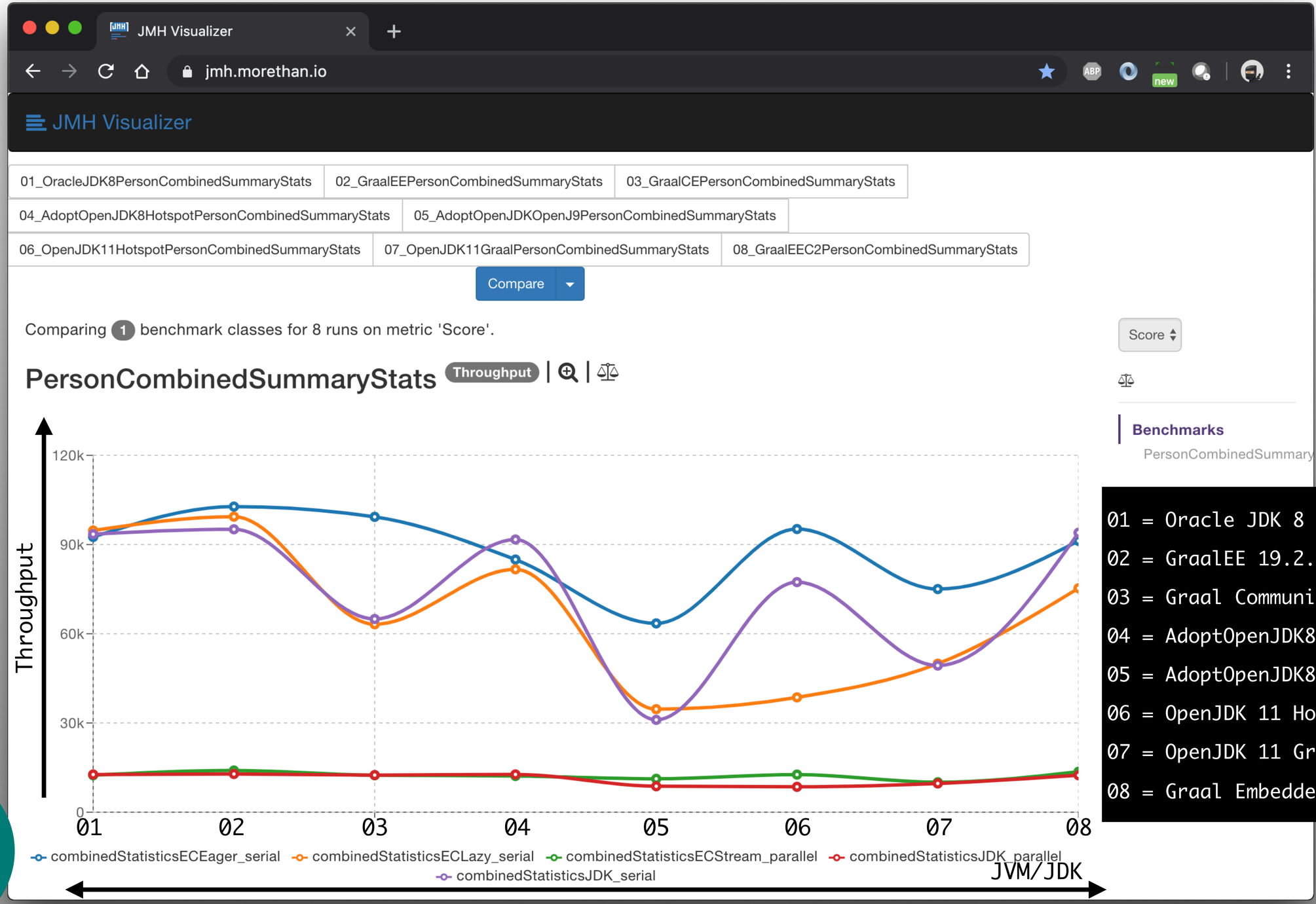

```
01 = Oracle JDK 8
02 = GraalEE 19.2.0
03 = Graal Community 19.2.0
04 = AdoptOpenJDK8 Hotspot
05 = AdoptOpenJDK8 OpenJ9
06 = OpenJDK 11 Hotspot
07 = OpenJDK 11 Graal JVMCI
08 = Graal Embedded Hotspot
```

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