

Java Compilation Results

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```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57169:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 0,023 ms/op
```

```
Iteration 2: 0,022 ms/op
```

```
Iteration 3: 0,022 ms/op
```

```
Iteration 4: 0,022 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
0,022 ±(99.9%) 0,004 ms/op [Average]
```

```
(min, avg, max) = (0,022, 0,022, 0,023), stdev = 0,001
```

```
CI (99.9%): [0,018, 0,026] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57169:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:04:46

# Fork: 1 of 1

Iteration 1: 0,023 ms/op
Iteration 2: 0,022 ms/op
Iteration 3: 0,022 ms/op
Iteration 4: 0,023 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

0,022 ±(99.9%) 0,004 ms/op [Average]

(min, avg, max) = (0,022, 0,022, 0,023), stdev = 0,001

CI (99.9%): [0,018, 0,027] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57169:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:04:05

# Fork: 1 of 1

Iteration 1: 0,025 ms/op
Iteration 2: 0,024 ms/op
Iteration 3: 0,024 ms/op

```

Iteration 4: 0,024 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

0,024 ±(99.9%) 0,001 ms/op [Average]

(min, avg, max) = (0,024, 0,024, 0,025), stdev = 0,001

CI (99.9%): [0,023, 0,026] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:03:24

Fork: 1 of 1

Iteration 1: 0,025 ms/op

Iteration 2: 0,025 ms/op

Iteration 3: 0,025 ms/op

Iteration 4: 0,025 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

0,025 ±(99.9%) 0,001 ms/op [Average]

(min, avg, max) = (0,025, 0,025, 0,025), stdev = 0,001

CI (99.9%): [0,024, 0,026] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (sparsity = 0.0)

Run progress: 50,00% complete, ETA 00:02:43

Fork: 1 of 1

Iteration 1: 1,221 ms/op

Iteration 2: 1,110 ms/op

Iteration 3: 1,201 ms/op

Iteration 4: 1,208 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

1,185 ±(99.9%) 0,326 ms/op [Average]

(min, avg, max) = (1,110, 1,185, 1,221), stdev = 0,051

CI (99.9%): [0,859, 1,511] (assumes normal distribution)

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:02:02

Fork: 1 of 1

Iteration 1: 0,011 ms/op

Iteration 2: 0,010 ms/op

Iteration 3: 0,011 ms/op

Iteration 4: 0,011 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

0,011 ±(99.9%) 0,002 ms/op [Average]

(min, avg, max) = (0,010, 0,011, 0,011), stdev = 0,001

CI (99.9%): [0,009, 0,013] (assumes normal distribution)

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:01:21

Fork: 1 of 1

Iteration 1: 0,022 ms/op

Iteration 2: 0,023 ms/op

Iteration 3: 0,021 ms/op

Iteration 4: 0,021 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

0,022 ±(99.9%) 0,005 ms/op [Average]

(min, avg, max) = (0,021, 0,022, 0,023), stdev = 0,001

CI (99.9%): [0,017, 0,027] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57169:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:00:40

Fork: 1 of 1

Iteration 1: 0,021 ms/op

Iteration 2: 0,021 ms/op

Iteration 3: 0,021 ms/op

Iteration 4: 0,021 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

0,021 ±(99.9%) 0,003 ms/op [Average]

(min, avg, max) = (0,021, 0,021, 0,021), stdev = 0,001

CI (99.9%): [0,018, 0,024] (assumes normal distribution)

Run complete. Total time: 00:05:26

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on

why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.0	avgt	4	0,022	± 0,004	ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.9	avgt	4	0,022	± 0,004	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.0	avgt	4	0,024	± 0,001	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.9	avgt	4	0,025	± 0,001	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.0	avgt	4	1,185	± 0,326	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.9	avgt	4	0,011	± 0,002	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.0	avgt	4	0,022	± 0,005	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.9	avgt	4	0,021	± 0,003	ms/op

Process finished with exit code 0

64x64

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56852:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 0,172 ms/op
```

```
Iteration 2: 0,207 ms/op
```

```
Iteration 3: 0,172 ms/op
```

```
Iteration 4: 0,170 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
0,180 ±(99.9%) 0,114 ms/op [Average]
```

```
(min, avg, max) = (0,170, 0,180, 0,207), stdev = 0,018
```

```
CI (99.9%): [0,067, 0,294] (assumes normal distribution)
```

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56852:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:04:46

# Fork: 1 of 1

Iteration 1: 0,178 ms/op
Iteration 2: 0,195 ms/op
Iteration 3: 0,166 ms/op
Iteration 4: 0,172 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

0,178 ±(99.9%) 0,082 ms/op [Average]

(min, avg, max) = (0,166, 0,178, 0,195), stdev = 0,013

CI (99.9%): [0,096, 0,260] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

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Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:04:05

# Fork: 1 of 1

Iteration 1: 0,066 ms/op
Iteration 2: 0,065 ms/op
Iteration 3: 0,065 ms/op

```

Iteration 4: 0,065 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

0,065 ±(99.9%) 0,003 ms/op [Average]

(min, avg, max) = (0,065, 0,065, 0,066), stdev = 0,001

CI (99.9%): [0,062, 0,069] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56852:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:03:24

Fork: 1 of 1

Iteration 1: 0,070 ms/op

Iteration 2: 0,070 ms/op

Iteration 3: 0,074 ms/op

Iteration 4: 0,071 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

0,071 ±(99.9%) 0,013 ms/op [Average]

(min, avg, max) = (0,070, 0,071, 0,074), stdev = 0,002

CI (99.9%): [0,058, 0,085] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (sparsity = 0.0)

Run progress: 50,00% complete, ETA 00:02:43

Fork: 1 of 1

Iteration 1: 10,495 ms/op

Iteration 2: 9,911 ms/op

Iteration 3: 9,923 ms/op

Iteration 4: 9,215 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

9,886 ±(99.9%) 3,384 ms/op [Average]

(min, avg, max) = (9,215, 9,886, 10,495), stdev = 0,524

CI (99.9%): [6,502, 13,270] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:02:02

Fork: 1 of 1

Iteration 1: 0,118 ms/op

Iteration 2: 0,115 ms/op

Iteration 3: 0,120 ms/op

Iteration 4: 0,113 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

0,117 ±(99.9%) 0,019 ms/op [Average]

(min, avg, max) = (0,113, 0,117, 0,120), stdev = 0,003

CI (99.9%): [0,098, 0,136] (assumes normal distribution)

JMH version: 1.35

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:01:21

Fork: 1 of 1

Iteration 1: 0,167 ms/op

Iteration 2: 0,170 ms/op

Iteration 3: 0,181 ms/op

Iteration 4: 0,173 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

0,173 ±(99.9%) 0,040 ms/op [Average]

(min, avg, max) = (0,167, 0,173, 0,181), stdev = 0,006

CI (99.9%): [0,132, 0,213] (assumes normal distribution)

JMH version: 1.35

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Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:00:40

Fork: 1 of 1

Iteration 1: 0,174 ms/op

Iteration 2: 0,175 ms/op

Iteration 3: 0,173 ms/op

Iteration 4: 0,179 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

0,175 ±(99.9%) 0,018 ms/op [Average]

(min, avg, max) = (0,173, 0,175, 0,179), stdev = 0,003

CI (99.9%): [0,157, 0,194] (assumes normal distribution)

Run complete. Total time: 00:05:26

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why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.0	avgt	4	0,180	± 0,114	ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.9	avgt	4	0,178	± 0,082	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.0	avgt	4	0,065	± 0,003	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.9	avgt	4	0,071	± 0,013	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.0	avgt	4	9,886	± 3,384	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.9	avgt	4	0,117	± 0,019	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.0	avgt	4	0,173	± 0,040	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.9	avgt	4	0,175	± 0,018	ms/op

Process finished with exit code 0

128x128

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 1,652 ms/op
```

```
Iteration 2: 1,410 ms/op
```

```
Iteration 3: 1,424 ms/op
```

```
Iteration 4: 1,412 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
1,474 ±(99.9%) 0,767 ms/op [Average]
```

```
(min, avg, max) = (1,410, 1,474, 1,652), stdev = 0,119
```

```
CI (99.9%): [0,708, 2,241] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```



```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:04:46

# Fork: 1 of 1

Iteration 1: 1,518 ms/op
Iteration 2: 1,381 ms/op
Iteration 3: 1,434 ms/op
Iteration 4: 1,421 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

1,438 ±(99.9%) 0,373 ms/op [Average]

(min, avg, max) = (1,381, 1,438, 1,518), stdev = 0,058

CI (99.9%): [1,065, 1,812] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:04:05

# Fork: 1 of 1

Iteration 1: 0,363 ms/op
Iteration 2: 0,361 ms/op
Iteration 3: 0,353 ms/op

```

Iteration 4: 0,357 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

0,359 ±(99.9%) 0,029 ms/op [Average]

(min, avg, max) = (0,353, 0,359, 0,363), stdev = 0,004

CI (99.9%): [0,330, 0,388] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:03:24

Fork: 1 of 1

Iteration 1: 0,364 ms/op

Iteration 2: 0,375 ms/op

Iteration 3: 0,373 ms/op

Iteration 4: 0,374 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

0,371 ±(99.9%) 0,033 ms/op [Average]

(min, avg, max) = (0,364, 0,371, 0,375), stdev = 0,005

CI (99.9%): [0,339, 0,404] (assumes normal distribution)

JMH version: 1.35

```

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 50,00% complete, ETA 00:02:43

# Fork: 1 of 1

Iteration 1: 77,887 ms/op
Iteration 2: 77,363 ms/op
Iteration 3: 77,625 ms/op
Iteration 4: 79,287 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

78,041 ±(99.9%) 5,547 ms/op [Average]

(min, avg, max) = (77,363, 78,041, 79,287), stdev = 0,858

CI (99.9%): [72,494, 83,587] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

```

Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:02:02

Fork: 1 of 1

Iteration 1: 1,173 ms/op

Iteration 2: 1,146 ms/op

Iteration 3: 1,171 ms/op

Iteration 4: 1,175 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

1,166 ±(99.9%) 0,086 ms/op [Average]

(min, avg, max) = (1,146, 1,166, 1,175), stdev = 0,013

CI (99.9%): [1,080, 1,253] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:01:21

Fork: 1 of 1

Iteration 1: 1,502 ms/op

Iteration 2: 1,486 ms/op

Iteration 3: 1,454 ms/op

Iteration 4: 1,469 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

1,478 ±(99.9%) 0,135 ms/op [Average]

(min, avg, max) = (1,454, 1,478, 1,502), stdev = 0,021

CI (99.9%): [1,343, 1,613] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55950:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:00:40

Fork: 1 of 1

Iteration 1: 1,489 ms/op

Iteration 2: 1,466 ms/op

Iteration 3: 1,500 ms/op

Iteration 4: 1,523 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

1,494 ±(99.9%) 0,153 ms/op [Average]

(min, avg, max) = (1,466, 1,494, 1,523), stdev = 0,024

CI (99.9%): [1,342, 1,647] (assumes normal distribution)

Run complete. Total time: 00:05:27

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on

why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.0	avgt	4	1,474	± 0,767	ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.9	avgt	4	1,438	± 0,373	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.0	avgt	4	0,359	± 0,029	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.9	avgt	4	0,371	± 0,033	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.0	avgt	4	78,041	± 5,547	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.9	avgt	4	1,166	± 0,086	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.0	avgt	4	1,478	± 0,135	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.9	avgt	4	1,494	± 0,153	ms/op

Process finished with exit code 0

256x256

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 12,479 ms/op
```

```
Iteration 2: 12,666 ms/op
```

```
Iteration 3: 12,541 ms/op
```

```
Iteration 4: 12,614 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
12,575 ±(99.9%) 0,532 ms/op [Average]
```

```
(min, avg, max) = (12,479, 12,575, 12,666), stdev = 0,082
```

```
CI (99.9%): [12,043, 13,106] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:04:46

# Fork: 1 of 1

Iteration 1: 12,548 ms/op
Iteration 2: 12,940 ms/op
Iteration 3: 12,370 ms/op
Iteration 4: 12,266 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

12,531 ±(99.9%) 1,917 ms/op [Average]

(min, avg, max) = (12,266, 12,531, 12,940), stdev = 0,297

CI (99.9%): [10,614, 14,448] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:04:05

# Fork: 1 of 1

Iteration 1: 4,514 ms/op
Iteration 2: 4,451 ms/op
Iteration 3: 4,419 ms/op

```


Iteration 4: 4,595 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

4,495 ±(99.9%) 0,502 ms/op [Average]

(min, avg, max) = (4,419, 4,495, 4,595), stdev = 0,078

CI (99.9%): [3,993, 4,996] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:03:24

Fork: 1 of 1

Iteration 1: 4,791 ms/op

Iteration 2: 4,681 ms/op

Iteration 3: 4,741 ms/op

Iteration 4: 4,776 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

4,747 ±(99.9%) 0,316 ms/op [Average]

(min, avg, max) = (4,681, 4,747, 4,791), stdev = 0,049

CI (99.9%): [4,432, 5,063] (assumes normal distribution)

JMH version: 1.35

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 50,00% complete, ETA 00:02:43
```

```
# Fork: 1 of 1
```

```
Iteration 1: 739,856 ms/op
```

```
Iteration 2: 696,889 ms/op
```

```
Iteration 3: 695,038 ms/op
```

```
Iteration 4: 687,209 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":
```

```
704,748 ±(99.9%) 153,655 ms/op [Average]
```

```
(min, avg, max) = (687,209, 704,748, 739,856), stdev = 23,778
```

```
CI (99.9%): [551,092, 858,403] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```
# Threads: 1 thread, will synchronize iterations
```

```
# Benchmark mode: Average time, time/op
```

```
# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication
```

Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:02:03

Fork: 1 of 1

Iteration 1: 9,957 ms/op

Iteration 2: 9,829 ms/op

Iteration 3: 9,886 ms/op

Iteration 4: 9,453 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

9,781 ±(99.9%) 1,456 ms/op [Average]

(min, avg, max) = (9,453, 9,781, 9,957), stdev = 0,225

CI (99.9%): [8,325, 11,238] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:01:22

Fork: 1 of 1

Iteration 1: 16,160 ms/op

Iteration 2: 15,516 ms/op

Iteration 3: 15,534 ms/op

Iteration 4: 15,299 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

15,627 ±(99.9%) 2,398 ms/op [Average]

(min, avg, max) = (15,299, 15,627, 16,160), stdev = 0,371

CI (99.9%): [13,229, 18,026] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56669:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:00:41

Fork: 1 of 1

Iteration 1: 16,758 ms/op

Iteration 2: 16,507 ms/op

Iteration 3: 16,905 ms/op

Iteration 4: 16,403 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

16,643 ±(99.9%) 1,482 ms/op [Average]

(min, avg, max) = (16,403, 16,643, 16,905), stdev = 0,229

CI (99.9%): [15,162, 18,125] (assumes normal distribution)

Run complete. Total time: 00:05:28

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on

why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.0	avgt 4	12,575 ± 0,532 ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.9	avgt 4	12,531 ± 1,917 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.0	avgt 4	4,495 ± 0,502 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.9	avgt 4	4,747 ± 0,316 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.0	avgt 4	704,748 ± 153,655 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.9	avgt 4	9,781 ± 1,456 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.0	avgt 4	15,627 ± 2,398 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.9	avgt 4	16,643 ± 1,482 ms/op

Process finished with exit code 0

512x512

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 107,804 ms/op
```

```
Iteration 2: 104,990 ms/op
```

```
Iteration 3: 102,300 ms/op
```

```
Iteration 4: 100,186 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
103,820 ±(99.9%) 21,355 ms/op [Average]
```

```
(min, avg, max) = (100,186, 103,820, 107,804), stdev = 3,305
```

```
CI (99.9%): [82,465, 125,175] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:04:47

# Fork: 1 of 1

Iteration 1: 101,441 ms/op
Iteration 2: 102,766 ms/op
Iteration 3: 101,581 ms/op
Iteration 4: 102,425 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

102,053 ±(99.9%) 4,161 ms/op [Average]
(min, avg, max) = (101,441, 102,053, 102,766), stdev = 0,644
CI (99.9%): [97,892, 106,214] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:04:06

# Fork: 1 of 1

Iteration 1: 36,453 ms/op
Iteration 2: 36,403 ms/op
Iteration 3: 36,795 ms/op

```

Iteration 4: 36,825 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

36,619 ±(99.9%) 1,434 ms/op [Average]

(min, avg, max) = (36,403, 36,619, 36,825), stdev = 0,222

CI (99.9%): [35,185, 38,053] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:03:25

Fork: 1 of 1

Iteration 1: 38,254 ms/op

Iteration 2: 37,679 ms/op

Iteration 3: 38,316 ms/op

Iteration 4: 38,048 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

38,074 ±(99.9%) 1,858 ms/op [Average]

(min, avg, max) = (37,679, 38,074, 38,316), stdev = 0,287

CI (99.9%): [36,216, 39,932] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (sparsity = 0.0)

Run progress: 50,00% complete, ETA 00:02:44

Fork: 1 of 1

Iteration 1: 6642,908 ms/op

Iteration 2: 6918,007 ms/op

Iteration 3: 6990,715 ms/op

Iteration 4: 6383,018 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

6733,662 ±(99.9%) 1794,086 ms/op [Average]

(min, avg, max) = (6383,018, 6733,662, 6990,715), stdev = 277,637

CI (99.9%): [4939,576, 8527,748] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:02:11

Fork: 1 of 1

Iteration 1: 87,550 ms/op

Iteration 2: 84,698 ms/op

Iteration 3: 81,393 ms/op

Iteration 4: 80,113 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

83,439 ±(99.9%) 21,670 ms/op [Average]

(min, avg, max) = (80,113, 83,439, 87,550), stdev = 3,353

CI (99.9%): [61,769, 105,108] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:01:26

Fork: 1 of 1

Iteration 1: 179,936 ms/op

Iteration 2: 176,507 ms/op

Iteration 3: 173,631 ms/op

Iteration 4: 174,131 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

176,051 ±(99.9%) 18,597 ms/op [Average]

(min, avg, max) = (173,631, 176,051, 179,936), stdev = 2,878

CI (99.9%): [157,454, 194,648] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=55630:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:00:43

Fork: 1 of 1

Iteration 1: 172,302 ms/op

Iteration 2: 173,375 ms/op

Iteration 3: 173,157 ms/op

Iteration 4: 174,357 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

173,297 ±(99.9%) 5,457 ms/op [Average]

(min, avg, max) = (172,302, 173,297, 174,357), stdev = 0,844

CI (99.9%): [167,841, 178,754] (assumes normal distribution)

Run complete. Total time: 00:05:42

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on

why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.0	avgt	4	103,820 ±	21,355	ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication	0.9	avgt	4	102,053 ±	4,161	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.0	avgt	4	36,619 ±	1,434	ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication	0.9	avgt	4	38,074 ±	1,858	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.0	avgt	4	6733,662 ±	1794,086	ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	0.9	avgt	4	83,439 ±	21,670	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.0	avgt	4	176,051 ±	18,597	ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication	0.9	avgt	4	173,297 ±	5,457	ms/op

Process finished with exit code 0

1024x1024

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 1015,989 ms/op
```

```
Iteration 2: 974,792 ms/op
```

```
Iteration 3: 959,864 ms/op
```

```
Iteration 4: 961,515 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
978,040 ±(99.9%) 169,092 ms/op [Average]
```

```
(min, avg, max) = (959,864, 978,040, 1015,989), stdev = 26,167
```

```
CI (99.9%): [808,948, 1147,132] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:05:02

# Fork: 1 of 1

Iteration 1: 934,017 ms/op
Iteration 2: 913,689 ms/op
Iteration 3: 903,033 ms/op
Iteration 4: 911,359 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

915,524 ±(99.9%) 84,973 ms/op [Average]

(min, avg, max) = (903,033, 915,524, 934,017), stdev = 13,150

CI (99.9%): [830,551, 1000,498] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:04:16

# Fork: 1 of 1

Iteration 1: 726,519 ms/op
Iteration 2: 725,840 ms/op
Iteration 3: 734,580 ms/op

```

Iteration 4: 735,544 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

730,621 ±(99.9%) 33,284 ms/op [Average]

(min, avg, max) = (725,840, 730,621, 735,544), stdev = 5,151

CI (99.9%): [697,336, 763,905] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:03:32

Fork: 1 of 1

Iteration 1: 772,949 ms/op

Iteration 2: 768,346 ms/op

Iteration 3: 772,498 ms/op

Iteration 4: 784,216 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

774,502 ±(99.9%) 43,935 ms/op [Average]

(min, avg, max) = (768,346, 774,502, 784,216), stdev = 6,799

CI (99.9%): [730,567, 818,438] (assumes normal distribution)

JMH version: 1.35

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 50,00% complete, ETA 00:02:50
```

```
# Fork: 1 of 1
```

```
Iteration 1: 59146,297 ms/op
```

```
Iteration 2: 58147,949 ms/op
```

```
Iteration 3: 56331,769 ms/op
```

```
Iteration 4: 57486,811 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":
```

```
57778,207 ±(99.9%) 7632,693 ms/op [Average]
```

```
(min, avg, max) = (56331,769, 57778,207, 59146,297), stdev = 1181,168
```

```
CI (99.9%): [50145,513, 65410,900] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```
# Threads: 1 thread, will synchronize iterations
```

```
# Benchmark mode: Average time, time/op
```

```
# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication
```


Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:04:01

Fork: 1 of 1

Iteration 1: 1143,771 ms/op

Iteration 2: 1077,596 ms/op

Iteration 3: 987,971 ms/op

Iteration 4: 970,252 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

1044,898 ±(99.9%) 523,086 ms/op [Average]

(min, avg, max) = (970,252, 1044,898, 1143,771), stdev = 80,948

CI (99.9%): [521,812, 1567,983] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:02:28

Fork: 1 of 1

Iteration 1: 3586,865 ms/op

Iteration 2: 3166,176 ms/op

Iteration 3: 3005,485 ms/op

Iteration 4: 2834,639 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

3148,291 ±(99.9%) 2082,050 ms/op [Average]

(min, avg, max) = (2834,639, 3148,291, 3586,865), stdev = 322,199

CI (99.9%): [1066,241, 5230,341] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=56297:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:01:10

Fork: 1 of 1

Iteration 1: 3343,999 ms/op

Iteration 2: 3203,529 ms/op

Iteration 3: 3231,130 ms/op

Iteration 4: 3283,155 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

3265,453 ±(99.9%) 400,008 ms/op [Average]

(min, avg, max) = (3203,529, 3265,453, 3343,999), stdev = 61,902

CI (99.9%): [2865,445, 3665,462] (assumes normal distribution)

Run complete. Total time: 00:09:03

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on

why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.0	avgt 4	978,040 ± 169,092 ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.9	avgt 4	915,524 ± 84,973 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.0	avgt 4	730,621 ± 33,284 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.9	avgt 4	774,502 ± 43,935 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.0	avgt 4	57778,207 ± 7632,693 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.9	avgt 4	1044,898 ± 523,086 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.0	avgt 4	3148,291 ± 2082,050 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.9	avgt 4	3265,453 ± 400,008 ms/op

Process finished with exit code 0

2048x2048

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 0,00% complete, ETA 00:05:20
```

```
# Fork: 1 of 1
```

```
Iteration 1: 9452,429 ms/op
```

```
Iteration 2: 7772,325 ms/op
```

```
Iteration 3: 7702,142 ms/op
```

```
Iteration 4: 7921,258 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
8212,039 ±(99.9%) 5376,106 ms/op [Average]
```

```
(min, avg, max) = (7702,142, 8212,039, 9452,429), stdev = 831,958
```

```
CI (99.9%): [2835,933, 13588,144] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 12,50% complete, ETA 00:07:52

# Fork: 1 of 1

Iteration 1: 9526,992 ms/op
Iteration 2: 7793,819 ms/op
Iteration 3: 7865,084 ms/op
Iteration 4: 7748,431 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

8233,581 ±(99.9%) 5580,634 ms/op [Average]

(min, avg, max) = (7748,431, 8233,581, 9526,992), stdev = 863,609

CI (99.9%): [2652,947, 13814,216] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 25,00% complete, ETA 00:06:43

# Fork: 1 of 1

Iteration 1: 8992,714 ms/op
Iteration 2: 9153,749 ms/op
Iteration 3: 9503,814 ms/op

```

Iteration 4: 9874,024 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

9381,075 ±(99.9%) 2531,925 ms/op [Average]

(min, avg, max) = (8992,714, 9381,075, 9874,024), stdev = 391,818

CI (99.9%): [6849,150, 11913,000] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

Parameters: (sparsity = 0.9)

Run progress: 37,50% complete, ETA 00:05:51

Fork: 1 of 1

Iteration 1: 10491,070 ms/op

Iteration 2: 9306,402 ms/op

Iteration 3: 8973,796 ms/op

Iteration 4: 9011,586 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

9445,714 ±(99.9%) 4604,743 ms/op [Average]

(min, avg, max) = (8973,796, 9445,714, 10491,070), stdev = 712,589

CI (99.9%): [4840,971, 14050,456] (assumes normal distribution)

JMH version: 1.35

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 50,00% complete, ETA 00:04:37
```

```
# Fork: 1 of 1
```

```
Iteration 1: 483973,968 ms/op
```

```
Iteration 2: 469512,523 ms/op
```

```
Iteration 3: 484993,648 ms/op
```

```
Iteration 4: 470221,343 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":
```

```
477175,371 ±(99.9%) 54631,411 ms/op [Average]
```

```
(min, avg, max) = (469512,523, 477175,371, 484993,648), stdev = 8454,271
```

```
CI (99.9%): [422543,959, 531806,782] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```
# Threads: 1 thread, will synchronize iterations
```

```
# Benchmark mode: Average time, time/op
```

```
# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication
```

Parameters: (sparsity = 0.9)

Run progress: 62,50% complete, ETA 00:21:52

Fork: 1 of 1

Iteration 1: 10866,827 ms/op

Iteration 2: 10456,491 ms/op

Iteration 3: 9833,037 ms/op

Iteration 4: 10255,465 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

10352,955 ±(99.9%) 2778,413 ms/op [Average]

(min, avg, max) = (9833,037, 10352,955, 10866,827), stdev = 429,963

CI (99.9%): [7574,541, 13131,368] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.0)

Run progress: 75,00% complete, ETA 00:12:26

Fork: 1 of 1

Iteration 1: 55566,971 ms/op

Iteration 2: 54880,680 ms/op

Iteration 3: 54911,199 ms/op

Iteration 4: 52058,453 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

54354,326 ±(99.9%) 10099,945 ms/op [Average]

(min, avg, max) = (52058,453, 54354,326, 55566,971), stdev = 1562,978

CI (99.9%): [44254,381, 64454,271] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=57417:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 87,50% complete, ETA 00:05:51

Fork: 1 of 1

Iteration 1: 52276,838 ms/op

Iteration 2: 52443,745 ms/op

Iteration 3: 52345,529 ms/op

Iteration 4: 52667,105 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

52433,304 ±(99.9%) 1100,173 ms/op [Average]

(min, avg, max) = (52276,838, 52433,304, 52667,105), stdev = 170,253

CI (99.9%): [51333,131, 53533,477] (assumes normal distribution)

Run complete. Total time: 00:44:30

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on

why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial

experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.0	avgt 4	8212,039 ± 5376,106 ms/op
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.9	avgt 4	8233,581 ± 5580,634 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.0	avgt 4	9381,075 ± 2531,925 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.9	avgt 4	9445,714 ± 4604,743 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.0	avgt 4	477175,371 ± 54631,411 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.9	avgt 4	10352,955 ± 2778,413 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.0	avgt 4	54354,326 ± 10099,945 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.9	avgt 4	52433,304 ± 1100,173 ms/op

Process finished with exit code 0

4096x4096

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=60038:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.9)
```

```
# Run progress: 0,00% complete, ETA 00:02:40
```

```
# Fork: 1 of 1
```

```
Iteration 1: 100071,512 ms/op
```

```
Iteration 2: 94488,783 ms/op
```

```
Iteration 3: 68139,880 ms/op
```

```
Iteration 4: 69927,756 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":
```

```
83156,983 ±(99.9%) 106510,942 ms/op [Average]
```

```
(min, avg, max) = (68139,880, 83156,983, 100071,512), stdev = 16482,686
```

```
CI (99.9%): [≈ 0, 189667,925] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=60038:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```
# Measurement: 4 iterations, 10 s each
```

```
# Timeout: 10 min per iteration
```

```

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 25,00% complete, ETA 00:16:45

# Fork: 1 of 1

Iteration 1: 105854,420 ms/op
Iteration 2: 105399,394 ms/op
Iteration 3: 108979,635 ms/op
Iteration 4: 103575,091 ms/op


Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":

105952,135 ±(99.9%) 14512,487 ms/op [Average]

(min, avg, max) = (103575,091, 105952,135, 108979,635), stdev = 2245,823

CI (99.9%): [91439,648, 120464,622] (assumes normal distribution)


# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=60038:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 50,00% complete, ETA 00:12:40

# Fork: 1 of 1

Iteration 1: 100835,634 ms/op
Iteration 2: 94451,218 ms/op
Iteration 3: 93461,459 ms/op

```

Iteration 4: 89974,938 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

94680,812 ±(99.9%) 29273,745 ms/op [Average]

(min, avg, max) = (89974,938, 94680,812, 100835,634), stdev = 4530,144

CI (99.9%): [65407,067, 123954,557] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=60038:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication

Parameters: (sparsity = 0.9)

Run progress: 75,00% complete, ETA 00:06:20

Fork: 1 of 1

Iteration 1: 504377,537 ms/op

Iteration 2: 506630,496 ms/op

Iteration 3: 513532,398 ms/op

Iteration 4: 513032,508 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication":

509393,235 ±(99.9%) 29651,763 ms/op [Average]

(min, avg, max) = (504377,537, 509393,235, 513532,398), stdev = 4588,643

CI (99.9%): [479741,472, 539044,998] (assumes normal distribution)

Run complete. Total time: 00:53:01

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(sparsity)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication				0.9	avgt 4	83156,983 ± 106510,942 ms/op
MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication				0.9	avgt 4	105952,135 ± 14512,487 ms/op
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication				0.9	avgt 4	94680,812 ± 29273,745 ms/op
MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication				0.9	avgt 4	509393,235 ± 29651,763 ms/op

Process finished with exit code 0

8192x8192

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 0,00% complete, ETA 00:05:20

# Fork: 1 of 1

Iteration 1: <failure>
```

java.lang.OutOfMemoryError: Java heap space

```
    at java.base/java.lang.Integer.valueOf(Integer.java:1081)
    at org.example.SparseMatrix.set(SparseMatrix.java:19)
    at org.example.MatrixMultiplicationBenchmarking.generateSparseMatrix(MatrixMultiplicationBenchmarking.java:58)
    at org.example.MatrixMultiplicationBenchmarking.setUp(MatrixMultiplicationBenchmarking.java:35)
    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkBlockedMultiplication_jmhTest._jmh_tryInit_f_matrixmul
tiplicationbenchmarking0_G(MatrixMultiplicationBenchmarking_benchmarkBlockedMultiplication_jmhTest.java:438)
    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkBlockedMultiplication_jmhTest.benchmarkBlockedMulti
plication_AverageTime(MatrixMultiplicationBenchmarking_benchmarkBlockedMultiplication_jmhTest.java:161)
    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:77)
    at java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)
    at java.base/java.lang.reflect.Method.invoke(Method.java:569)
    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:475)
    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:458)
    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)
    at java.base/java.util.concurrent.Executors$RunnableAdapter.call(Executors.java:539)
    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)
    at java.base/java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1136)
```

at java.base/java.util.concurrent.ThreadPoolExecutor\$Worker.run(ThreadPoolExecutor.java:635)

at java.base/java.lang.Thread.run(Thread.java:840)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: <none>

Measurement: 4 iterations, 10 s each

Timeout: 10 min per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication

Parameters: (sparsity = 0.9)

Run progress: 12,50% complete, ETA 00:02:04

Fork: 1 of 1

Iteration 1: 636176,645 ms/op

Iteration 2: 6846800,312 ms/op

Iteration 3: 747080,124 ms/op

Iteration 4: 619436,362 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkBlockedMultiplication":

2212373,361 ±(99.9%) 19968432,904 ms/op [Average]

(min, avg, max) = (619436,362, 2212373,361, 6846800,312), stdev = 3090137,096

CI (99.9%): [≈ 0, 22180806,264] (assumes normal distribution)

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8


```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.0)
```

```
# Run progress: 25,00% complete, ETA 07:23:36
```

```
# Fork: 1 of 1
```

```
Iteration 1: <failure>
```

```
java.lang.OutOfMemoryError: Java heap space
```

```
    at java.base/java.util.HashMap.newNode(HashMap.java:1901)
    at java.base/java.util.HashMap.putVal(HashMap.java:629)
    at java.base/java.util.HashMap.put(HashMap.java:610)
    at org.example.SparseMatrix.set(SparseMatrix.java:19)
    at org.example.MatrixMultiplicationBenchmarking.generateSparseMatrix(MatrixMultiplicationBenchmarking.java:58)
    at org.example.MatrixMultiplicationBenchmarking.setUp(MatrixMultiplicationBenchmarking.java:35)
    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkParallelStreamsMultiplication_jmhTest._jmh_tryInit_f_m
atrixmultiplicationbenchmarking0_G(MatrixMultiplicationBenchmarking_benchmarkParallelStreamsMultiplication_jmhTest.java:438
)
    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkParallelStreamsMultiplication_jmhTest.benchmarkParall
elStreamsMultiplication_AverageTime(MatrixMultiplicationBenchmarking_benchmarkParallelStreamsMultiplication_jmhTest.java:16
1)
    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:77)
    at java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)
    at java.base/java.lang.reflect.Method.invoke(Method.java:569)
    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:475)
    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:458)
    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)
    at java.base/java.util.concurrent.Executors$RunnableAdapter.call(Executors.java:539)
    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)
    at java.base/java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1136)
    at java.base/java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.java:635)
    at java.base/java.lang.Thread.run(Thread.java:840)
```

```
# JMH version: 1.35

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication

# Parameters: (sparsity = 0.9)
```

```
# Run progress: 37,50% complete, ETA 04:06:59
```

```
# Fork: 1 of 1
```

```
Iteration 1: 1032461,710 ms/op
```

```
Iteration 2: 1030606,991 ms/op
```

```
Iteration 3: 945699,367 ms/op
```

```
Iteration 4: 1070193,298 ms/op
```

```
Result "org.example.MatrixMultiplicationBenchmarking.benchmarkParallelStreamsMultiplication":
```

```
1019740,341 ±(99.9%) 340048,110 ms/op [Average]
```

```
(min, avg, max) = (945699,367, 1019740,341, 1070193,298), stdev = 52622,822
```

```
CI (99.9%): [679692,231, 1359788,452] (assumes normal distribution)
```

```
# JMH version: 1.35
```

```
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
```

```
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
```

```
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
```

```
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
```

```
# Warmup: <none>
```

```

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.0)


# Run progress: 50,00% complete, ETA 03:36:15

# Fork: 1 of 1

Iteration 1: <failure>


java.lang.OutOfMemoryError: Java heap space

    at java.base/java.lang.Integer.valueOf(Integer.java:1081)

    at org.example.SparseMatrix.set(SparseMatrix.java:19)

    at org.example.MatrixMultiplicationBenchmarking.generateSparseMatrix(MatrixMultiplicationBenchmarking.java:58)

    at org.example.MatrixMultiplicationBenchmarking.setUp(MatrixMultiplicationBenchmarking.java:35)

    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest._jmh_tryInit_f_matrixmulti
plicationbenchmarking0_G(MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.java:438)

    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.benchmarkSparseMultipli
cation_AverageTime(MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.java:161)

    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)

    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:77)

    at java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)

    at java.base/java.lang.reflect.Method.invoke(Method.java:569)

    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:475)

    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:458)

    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)

    at java.base/java.util.concurrent.Executors$RunnableAdapter.call(Executors.java:539)

    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)

    at java.base/java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1136)

    at java.base/java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.java:635)

    at java.base/java.lang.Thread.run(Thread.java:840)


# JMH version: 1.35

```

```

# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

# Warmup: <none>

# Measurement: 4 iterations, 10 s each

# Timeout: 10 min per iteration

# Threads: 1 thread, will synchronize iterations

# Benchmark mode: Average time, time/op

# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

# Parameters: (sparsity = 0.9)


# Run progress: 62,50% complete, ETA 02:09:56

# Fork: 1 of 1

Iteration 1: <failure>


java.lang.OutOfMemoryError: Java heap space

    at java.base/java.lang.Integer.valueOf(Integer.java:1081)

    at org.example.SparseMatrix.get(SparseMatrix.java:24)

    at org.example.SparseMatrixMultiplication.execute(SparseMatrixMultiplication.java:24)

    at
org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication(MatrixMultiplicationBenchmarking.java:77)

    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.benchmarkSparseMultipli
cation_avgT_jmhStub(MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.java:232)

    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.benchmarkSparseMultipli
cation_AverageTime(MatrixMultiplicationBenchmarking_benchmarkSparseMultiplication_jmhTest.java:173)

    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)

    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:77)

    at java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)

    at java.base/java.lang.reflect.Method.invoke(Method.java:569)

    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:475)

    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:458)

    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)

    at java.base/java.util.concurrent.Executors$RunnableAdapter.call(Executors.java:539)

    at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)

    at java.base/java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1136)

    at java.base/java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.java:635)

```

```

at java.base/java.lang.Thread.run(Thread.java:840)

# JMH version: 1.35
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
# Warmup: <none>
# Measurement: 4 iterations, 10 s each
# Timeout: 10 min per iteration
# Threads: 1 thread, will synchronize iterations
# Benchmark mode: Average time, time/op
# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication
# Parameters: (sparsity = 0.0)

# Run progress: 75,00% complete, ETA 01:20:12
# Fork: 1 of 1
Iteration 1: <failure>

java.lang.OutOfMemoryError: Java heap space

    at java.base/java.lang.Double.valueOf(Double.java:632)
    at org.example.SparseMatrix.set(SparseMatrix.java:19)
    at org.example.MatrixMultiplicationBenchmarking.generateSparseMatrix(MatrixMultiplicationBenchmarking.java:58)
    at org.example.MatrixMultiplicationBenchmarking.setUp(MatrixMultiplicationBenchmarking.java:35)
    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkStandardMultiplication_jmhTest._jmh_tryInit_f_matrixm
ultiplicationbenchmarking0_G(MatrixMultiplicationBenchmarking_benchmarkStandardMultiplication_jmhTest.java:438)
    at
org.example.jmh_generated.MatrixMultiplicationBenchmarking_benchmarkStandardMultiplication_jmhTest.benchmarkStandardMu
ltiplication_AverageTime(MatrixMultiplicationBenchmarking_benchmarkStandardMultiplication_jmhTest.java:161)
    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)
    at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:77)
    at java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)
    at java.base/java.lang.reflect.Method.invoke(Method.java:569)
    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:475)
    at org.openjdk.jmh.runner.BenchmarkHandler$BenchmarkTask.call(BenchmarkHandler.java:458)

```

```

at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)
at java.base/java.util.concurrent.Executors$RunnableAdapter.call(Executors.java:539)
at java.base/java.util.concurrent.FutureTask.run(FutureTask.java:264)
at java.base/java.util.concurrent.ThreadPoolExecutor.runWorker(ThreadPoolExecutor.java:1136)
at java.base/java.util.concurrent.ThreadPoolExecutor$Worker.run(ThreadPoolExecutor.java:635)
at java.base/java.lang.Thread.run(Thread.java:840)

# JMH version: 1.35
# VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11
# VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13-11-hotspot\bin\java.exe
# VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63039:C:\Program
Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8
# Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)
# Warmup: <none>
# Measurement: 4 iterations, 10 s each
# Timeout: 10 min per iteration
# Threads: 1 thread, will synchronize iterations
# Benchmark mode: Average time, time/op
# Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkStandardMultiplication
# Parameters: (sparsity = 0.9)

# Run progress: 87,50% complete, ETA 00:34:25
# Fork: 1 of 1
Iteration 1: 5173010,536 ms/op
Iteration 2:
Process finished with exit code 130

```

mc2depi

JMH version: 1.35

VM version: JDK 17.0.13, OpenJDK 64-Bit Server VM, 17.0.13+11

VM invoker: C:\Program Files\Eclipse Adoptium\jdk-17.0.13.11-hotspot\bin\java.exe

VM options: -javaagent:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\lib\idea_rt.jar=63356:C:\Program Files\JetBrains\IntelliJ IDEA Community Edition 2024.2.2\bin -Dfile.encoding=UTF-8

Blackhole mode: compiler (auto-detected, use -Djmh.blackhole.autoDetect=false to disable)

Warmup: 4 iterations, 10 s each

Measurement: 4 iterations, 10 s each

Timeout: 300 s per iteration

Threads: 1 thread, will synchronize iterations

Benchmark mode: Average time, time/op

Benchmark: org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication

Parameters: (matrixFilePath = ../../test_matrix/mc2depi.mtx)

Run progress: 0,00% complete, ETA 00:02:40

Fork: 1 of 2

Warmup Iteration 1: 983,143 ms/op

Warmup Iteration 2: 893,188 ms/op

Warmup Iteration 3: 881,945 ms/op

Warmup Iteration 4: 856,268 ms/op

Iteration 1: 826,991 ms/op

Iteration 2: 853,748 ms/op

Iteration 3: 873,989 ms/op

Iteration 4: 844,569 ms/op

Run progress: 50,00% complete, ETA 00:01:27

Fork: 2 of 2

Warmup Iteration 1: 988,040 ms/op

Warmup Iteration 2: 874,032 ms/op

Warmup Iteration 3: 877,966 ms/op

Warmup Iteration 4: 817,632 ms/op

Iteration 1: 834,445 ms/op

Iteration 2: 860,437 ms/op

Iteration 3: 831,492 ms/op

Iteration 4: 826,581 ms/op

Result "org.example.MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication":

844,032 ±(99.9%) 33,158 ms/op [Average]

(min, avg, max) = (826,581, 844,032, 873,989), stdev = 17,342

CI (99.9%): [810,873, 877,190] (assumes normal distribution)

Run complete. Total time: 00:02:55

REMEMBER: The numbers below are just data. To gain reusable insights, you need to follow up on why the numbers are the way they are. Use profilers (see -prof, -lprof), design factorial experiments, perform baseline and negative tests that provide experimental control, make sure the benchmarking environment is safe on JVM/OS/HW level, ask for reviews from the domain experts. Do not assume the numbers tell you what you want them to tell.

NOTE: Current JVM experimentally supports Compiler Blackholes, and they are in use. Please exercise extra caution when trusting the results, look into the generated code to check the benchmark still works, and factor in a small probability of new VM bugs. Additionally, while comparisons between different JVMs are already problematic, the performance difference caused by different Blackhole modes can be very significant. Please make sure you use the consistent Blackhole mode for comparisons.

Benchmark	(matrixFilePath)	Mode	Cnt	Score	Error	Units
MatrixMultiplicationBenchmarking.benchmarkSparseMultiplication	../test_matrix/mc2depi.mtx	avgt	8	844,032 ± 33,158	ms/op	

Process finished with exit code 0