





Marlin renderer, a JDK-9 Success Story

Vector Graphics on Steroids for Java 2D and JavaFX



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OpenJDK





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Context & History

Role of an Anti-aliasing Renderer



- Geometry is defined by a **mathematical description of a path**
- **Shapes** may be complex: concave, convex, intersecting ...
- To draw to any kind of raster surface (image, screen), need to map the rendering of ideal path to raster coordinates
- **Points on the path** may rarely map exactly to **raster coordinates**
- Need to ascertain **coverage (anti-aliasing)** for each output pixel





Java2D is a great & powerful Graphics API:

- Shape interface (`java.awt.geom`)
 - Primitives: `Rectangle2D`, `Line2D`, `Ellipse2D`, `Arc2D` ...
 - General `Path2D`: `moveTo()`, `lineTo()`, `quadTo()`, `curveTo()`, `closeTo()`
- Stroke interface: `BasicStroke` (width, dashes fields)
- Paint interface: `Color`, `GradientPaint`, `TexturePaint`
- Composite interface: `AlphaComposite` (Porter/Duff blending rules)
- Graphics interface: `Graphics2D draw(Shape)` or `fill(Shape)`
performs shape rendering operations

Background (before Marlin)



Anti-aliasing renderers available in Java:

- JDK 1.2 included licensed **closed-source** technology from **Ductus**
 - Ductus provides **high performance, but single threaded**
 - State of the art for its time
 - Ductus still ships with Oracle JDK-9
 - `sun.dc.DuctusRenderingEngine` (native C code)
- However **OpenJDK** 1.6 replaced Ductus with "**Pisces**"
 - Pisces developed + owned by Sun, in part for Java ME
 - So could be **open-sourced but performance much poorer**
 - `java2d.pisces.PiscesRenderingEngine` (java code)

Note: Other renderers for non-AA cases

Marlin renderer = OpenJDK's Pisces fork



Status in 2013:

- **OpenGL & D3D pipelines provide only few accelerated operations** (blending), except the `glg2d` `Graphics2D` implementation
- **Pisces is slower but open-source (GPL)**

2013.3: My first patches to OpenJDK-8:

- **Pisces patches** to `2d-dev@openjdk.java.net`: too late for JDK-8
- Small interest / few feedbacks

Andréa Aimé (GeoServer team) **pushed me to go on:**

- New **MapBench** tool: serialize & replay rendering commands
- **Fork OpenJDK's Pisces as a new open-source project**



⇒ 2014.1: **Marlin renderer** & MapBench projects @ github (GPL v2)

- <https://github.com/bourgesl/marlin-renderer>
 - branch '**openjdk-dev**': **dev branch**
 - branch 'openjdk': in sync with OpenJDK-9 & 10
 - branch '**use_Unsafe**': **main for Marlin releases**
 - [28 Releases](#), [Wiki](#)
- <https://github.com/bourgesl/mapbench>



Objectives:

- **Faster** alternative with very good scalability
- Improve rendering **quality**
- Compatible with both Oracle & Open JDK 7 / 8 / 9

Very big personal work:

- **Performance & Test Driven Development:**
 - **Regression** tests: MapDisplay (diff Pisces vs Marlin outputs)
 - **Performance** tests: MapBench benchmarks (+ profiler)
- Major feedback (GeoServer) providing use cases & testing releases

Marlin renderer back into OpenJDK-9



- **FOSDEM 2015:** Great discussion with OpenJDK managers (Dalibor & Mario) on how to contribute the Marlin renderer back
 - ⇒ I joined the **graphics-rasterizer** project in march 2015 to **contribute Marlin as a new standalone renderer for OpenJDK-9**
- I worked really hard (again, single developer) with Jim Graham & Phil Race (reviewers) in 2015 to push 4 big patches ≈ **10,000 LOC** !
- Reviews improved a lot the code and Computer Graphics algorithms



We proposed the JEP 265 in July 2015 and make it completed:

- **JEP 265: Marlin Graphics Renderer**
- <http://openjdk.java.net/jeps/265>
- **Developer: Laurent Bourgès**
- **Reviewer: Jim Graham**
- Marlin integrated in OpenJDK-9 b96 (dec 2015), enhancements in 2016
- Current **integrated releases** within OpenJDK:

JDK-9	Marlin 0.7.4
JDK-10	Marlin 0.7.5

Marlin Releases @ github



Major Releases:

Release	Main features
0.3 [2014.1]	Initial: renderer context, array cache, dirty array
0.4	Internal settings made customizable from system properties
0.5 [2014.3]	Use sun.misc.Unsafe (off-heap memory) (may crash your JVM)
0.5.6 [2015.3]	Optimized merge sort for newly added edges
0.7 [2015.8]	Improve coordinate rounding around sub-pixel center Perform DDA in scan-line edge processing Optimized cubic / quad flattening
0.7.1	Hybrid approach (raw or RLE) to copy pixel coverages into mask

Marlin Releases @ github (continued)



Major Releases:

Release	Main features
0.7.2 [2015.11]	Improve large pixel chunk copies (coverage)
0.7.3.3	Handle coordinate overflow : ignore (NaN / Infinity)
0.7.4 [2016.6]	Array cache refactoring & tuning [-> JDK-9]
0.7.5 [2016.12]	Added the Double pipeline for higher accuracy [-> JDK-10] Optimized tile filling (almost empty / full) Higher precision of the curve conversion to line segments
0.8.0 [2017.8]	Added path clipper for stroked shapes (cap, joins, tx)
0.8.1	Added path clipper for filled shapes (N.Z. winding rule)

Feedback on contributing to OpenJDK



- **Very interesting experience** & many things learnt
- **License issue: OCA** for all contributors, no third-party code !
- **Webrev process: great but heavy task:**
 - Create webrevs (hg status, webrev.ksh with options)
 - Push on <http://cr.openjdk.java.net/~lbourges/>
 - Long review threads on mailing lists for my patches (50 mails)
 - Timezone difference: delays + no direct discussion
- **Few Java2D / computer graphics skills:** small field + NO DOC !

Feedback on contributing to OpenJDK (continued)



In General:

- **Missing active contributors in the Graphics stack (Java2D & JavaFX) !**
- CI: missing 'open' multi-platform machines to perform tests & benchmarks outside of Oracle
- **Funding community-driven effort ?**
 - Support collaboration with outsiders (meeting, costs)
 - Promote Code challenges on focused items

How Marlin works ?



How the Java2D pipeline works ?

Java2D uses only 1 RenderingEngine implementation at runtime:

- SunGraphics2D.draw/fill(shape)
- AAShapePipe.renderPath(shape, stroke)
 - aatg = RenderingEngine.getAA TileGenerator(shape, at)
 - Coverage mask computation (tiles) as alpha transparency [0-255]
 - aatg.getAlpha(byte[] alpha, ...) to get next tile ...
 - output pipeline.renderPathTile(byte[] alpha):
 - MaskFill operations (software / OpenGL pipeline) on dest surface

1 RenderingEngine:

```
2     public static synchronized RenderingEngine getInstance();  
3     public AA TileGenerator getAA TileGenerator(Shape s,  
4                                         AffineTransform at, ...);
```

5 AA TileGenerator:

How Marlin works ? Pisces / Marlin pipeline



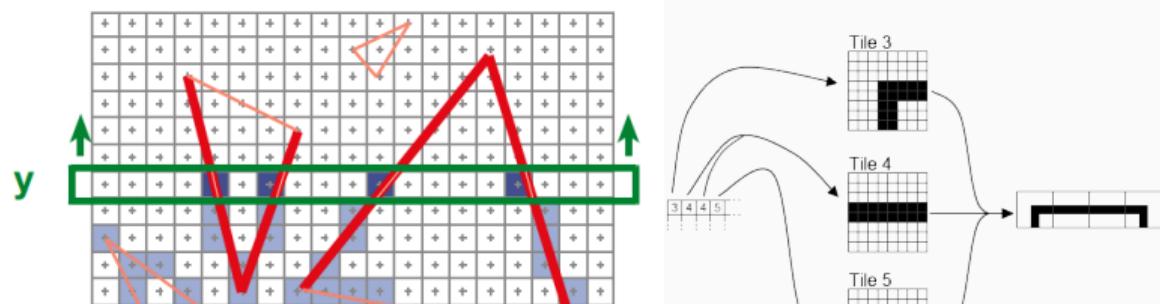
MarlinRenderingEngine.getAAATileGenerator(shape, stroke...):

- use shape.getPathIterator() ⇒ apply the pipeline to path elements:
- Dasher (optional):
 - generates path dashes (curved or segments)
- Stroker (optional):
 - generates edges around of every path element
 - generates edges for decorations (cap & joins)
- Renderer:
 - curve decimation into line segments
 - addLine: basic clipping + convert float to sub-pixel coordinates
 - determine the shape bounding box
 - perform edge rendering into tile strides ie compute pixel coverages
 - fill the MarlinCache with pixel coverages as byte[] (alpha)

How Marlin works ? the AA algorithm



- Scan-line algorithm [8x8 super-sampling] to estimate pixel coverages
- = Active Edge table (AET) variant with "java" pointers (integer-based)
 - sort edges at each scan-line
 - estimate sub-pixel coverage and accumulate in the alpha row
 - Once a pixel row is done: copy pixel coverages into cache
 - Once 32 (tile height) pixel rows are done: perform blending & repeat !



How Marlin works ? the AA algorithm



- Java2D's internal drawing renders rectangular tiles.
- Marlin starts with the path defining the shape
- Takes the elements of the path and flattens curves
- Uses 8x8 super-sampling to estimate coverage.
- For each sample line calculates intersections.
- Sorts where the path edges cross the scan line
- Output is one byte per pixel representing alpha coverage.
- Process 32 entire pixel rows at a time and cache sample-line intersection info
- Provide 32x32 rectangular tiles needed by the internal Java2D rendering pipelines

Marlin performance optimizations



- Initially GC allocation issue:
 - Many growing arrays + zero-fill
 - Many arrays involved to store edge data, alpha pixel row ...
 - Value-Types may be very helpful: manually coded here !
- Marlin RendererContext (TL/CLQ) = reused memory ⇒ almost no GC
 - kept by weak / soft reference
 - class instances + initial arrays takes 512Kb
 - weak-referenced array cache for larger arrays
- Other considerations:
 - Unsafe: allocate/free memory + less bound checks
 - zero-fill (recycle arrays) on used parts only !
 - use dirty arrays when possible: C like !

Marlin performance optimizations



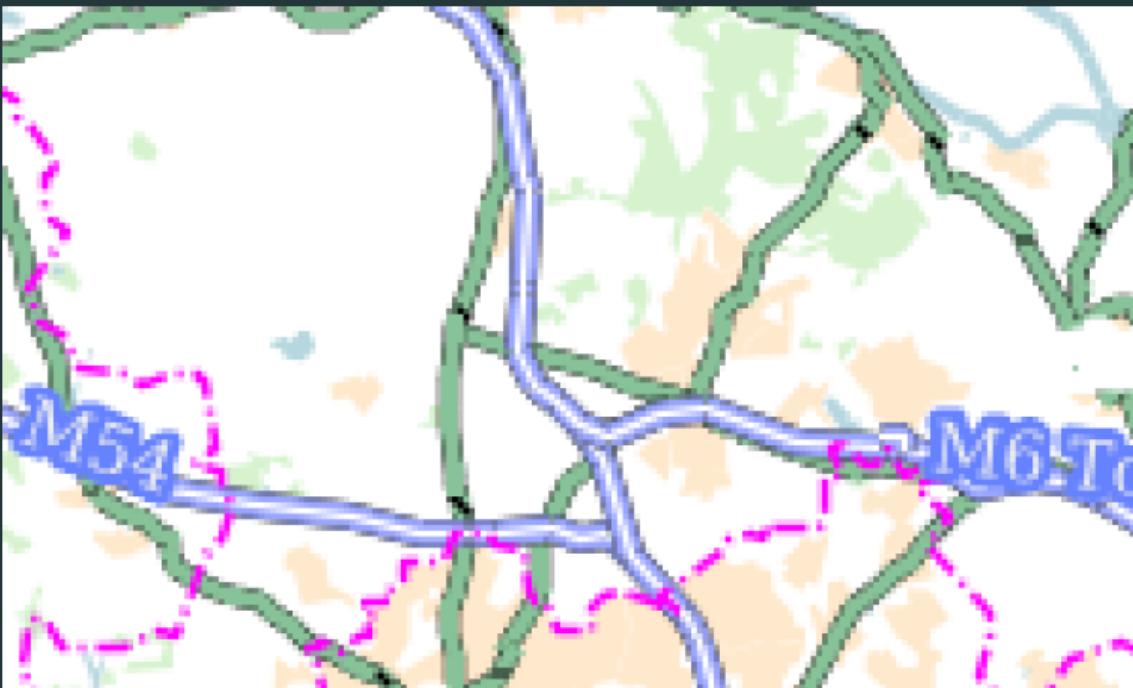
- Need good profiler: use oprofile + gather internal metrics
- Fine tuning of Pisces algorithms:
 - Optimized Merge Sort (in-place)
 - Custom rounding [float to int]
 - DDA in Renderer with correct pixel center handling
 - Tile stride approach (32px) instead of all shape mask
 - Pixel alpha transfers (RLE) \Rightarrow adaptive approach
 - Optimized Pixel copies (block flags)

A lot more ...

Visual quality Quiz



Who is [Ductus, Pisces, Marlin] ?





Who is [Ductus, Pisces, Marlin] ?



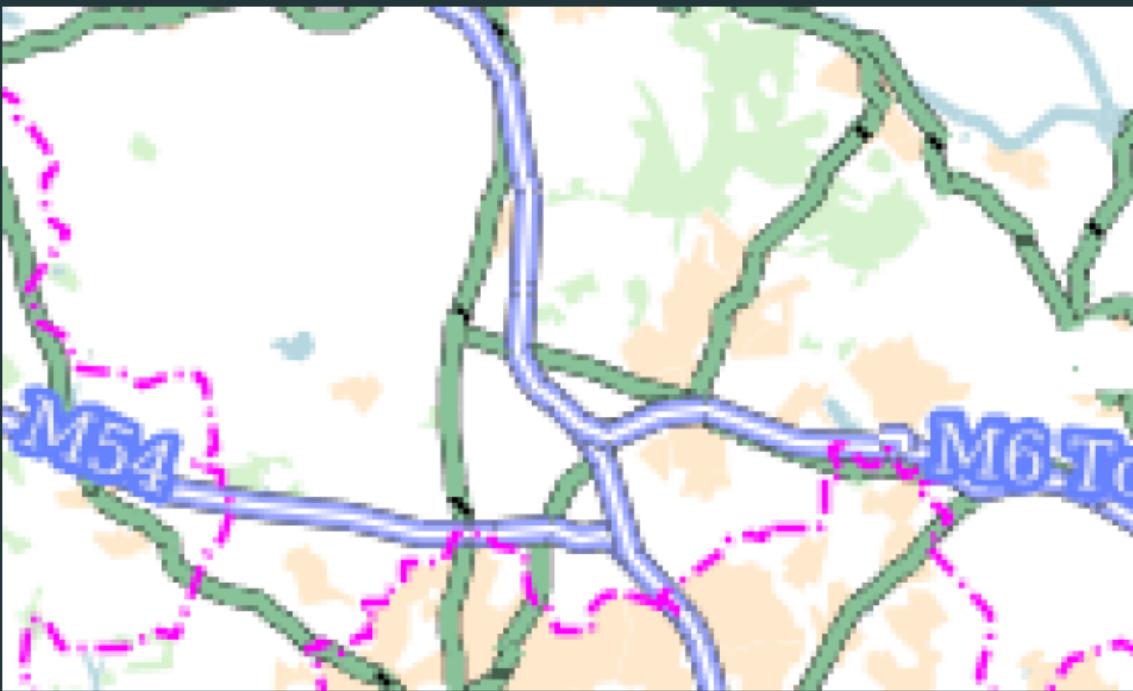


Who is [Ductus, Pisces, Marlin] ?



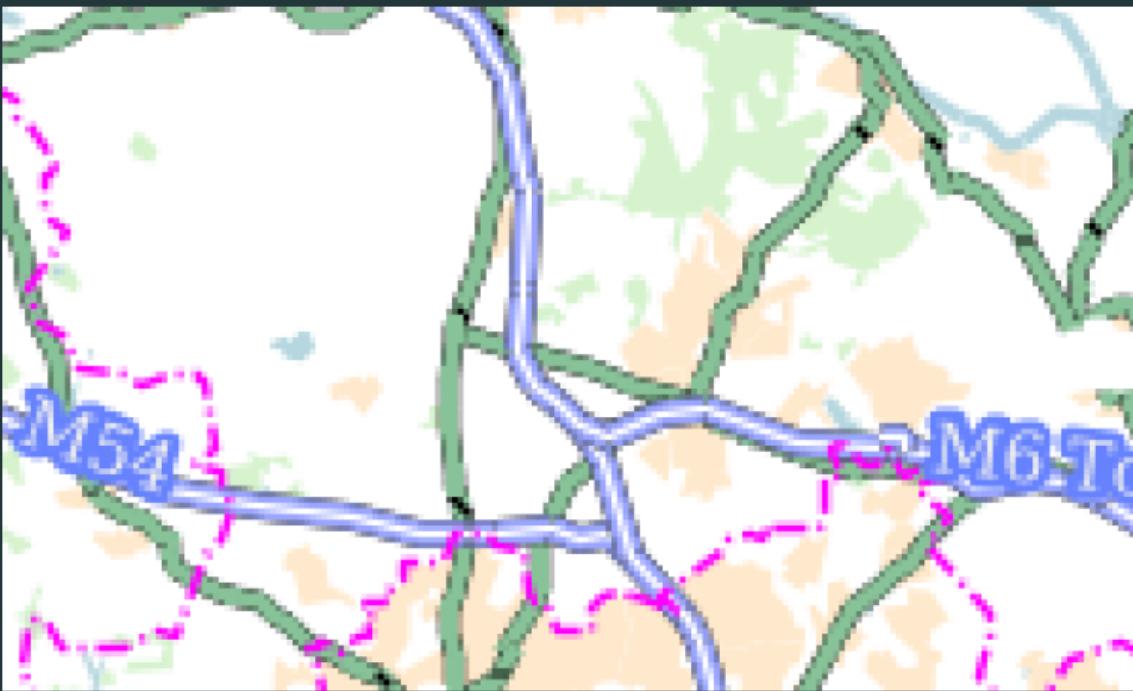


Answer: Ductus



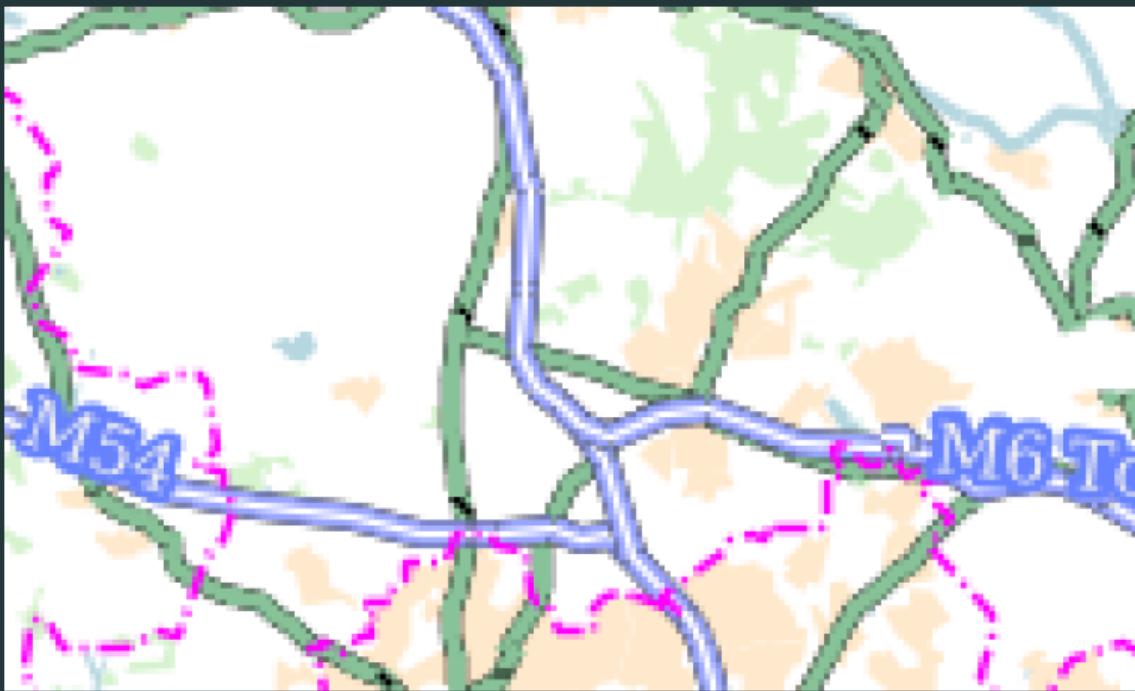


Answer: Marlin



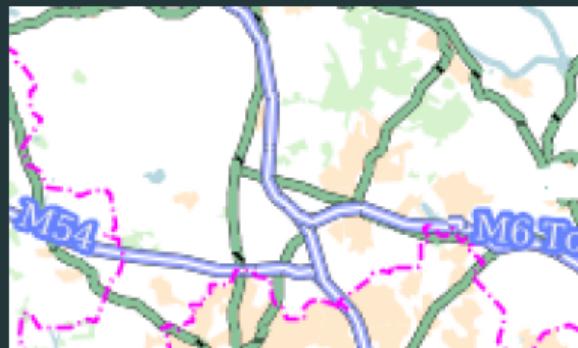


Answer: Pisces

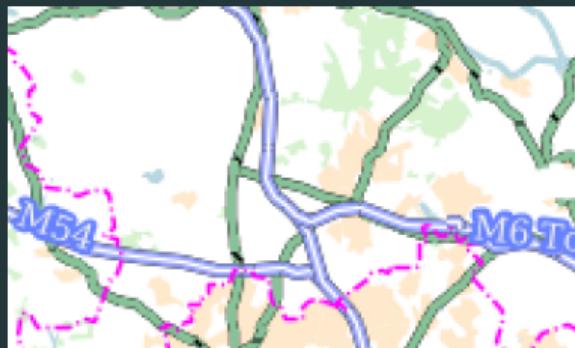




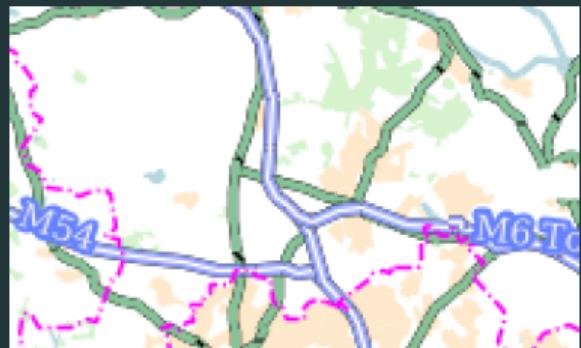
Who is [Ductus, Pisces, Marlin] ?



1. Ductus



2. Marlin



3. Pisces

⇒ Quite an hard challenge !

Marlin usage & benchmarks

How to use Marlin ?



- Just download any Oracle JDK-9 or OpenJDK-9 release
 - [Oracle JDK](#)
 - OpenJDK builds: [AdoptOpenJDK.net](#) or [zulu.org](#)
- For JDK 1.7 or JDK-8:
 - Download the latest [Marlin release @ github](#)
 - See [How to use](#)
 - Start your java program with:

```
1  java -Xbootclasspath/a:../lib/marlin-0.7.5-Unsafe.jar  
2    -Dsun.java2d.renderer=sun.java2d.marlin.MarlinRenderingEngine  
3    ...
```



MapBench benchmarks

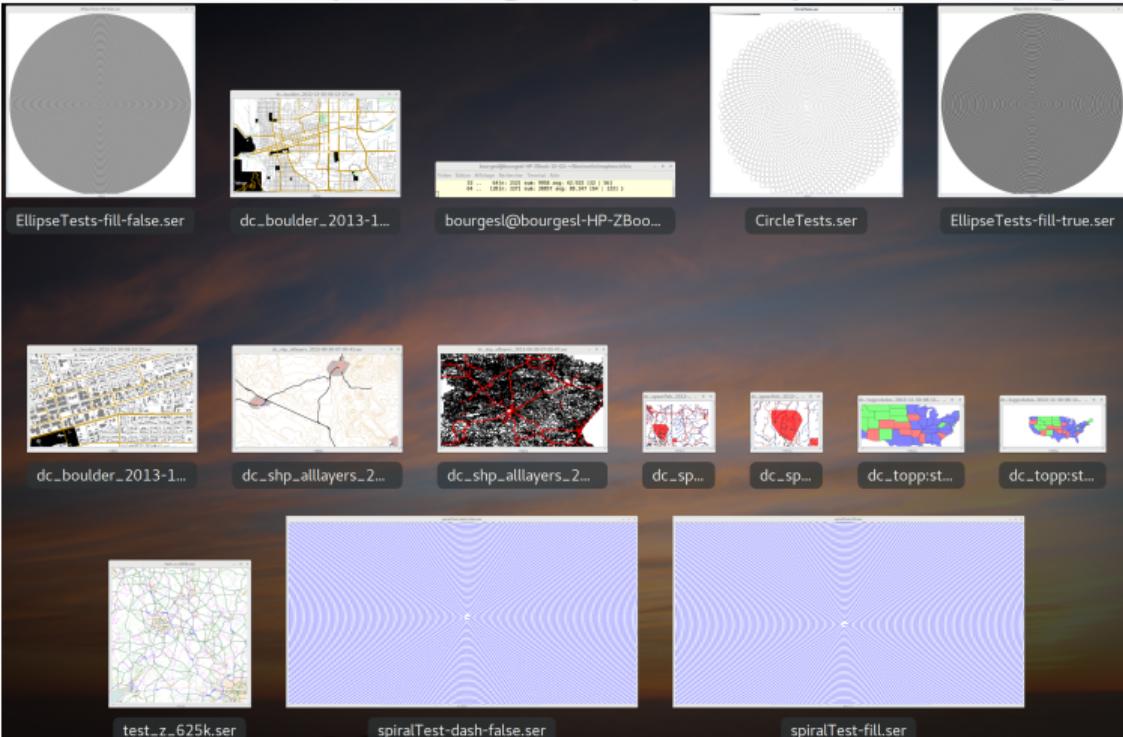
- MapBench tool:
 - Multi-threaded java2d benchmark that replays serialized graphics commands: see **ShapeDumperGraphics2D**
 - Calibration & warm-up phase at startup + correct statistics [95th percentile...]
- Protocol:
 - Disable Hyper-Threading (in BIOS)
 - Use fixed CPU frequencies (2.0 GHz) on my laptop (i7-6820 HQ)
 - Setup JVM: select JDK + basic jvm settings = CMS GC 2Gb Heap
 - Use the profile 'shared images' to reduce GC overhead

⇒ Reduce variability (and CPU affinity issues)

MapBench tests



- Test showcase: 9 maps, 5 large ellipse & spiral drawings



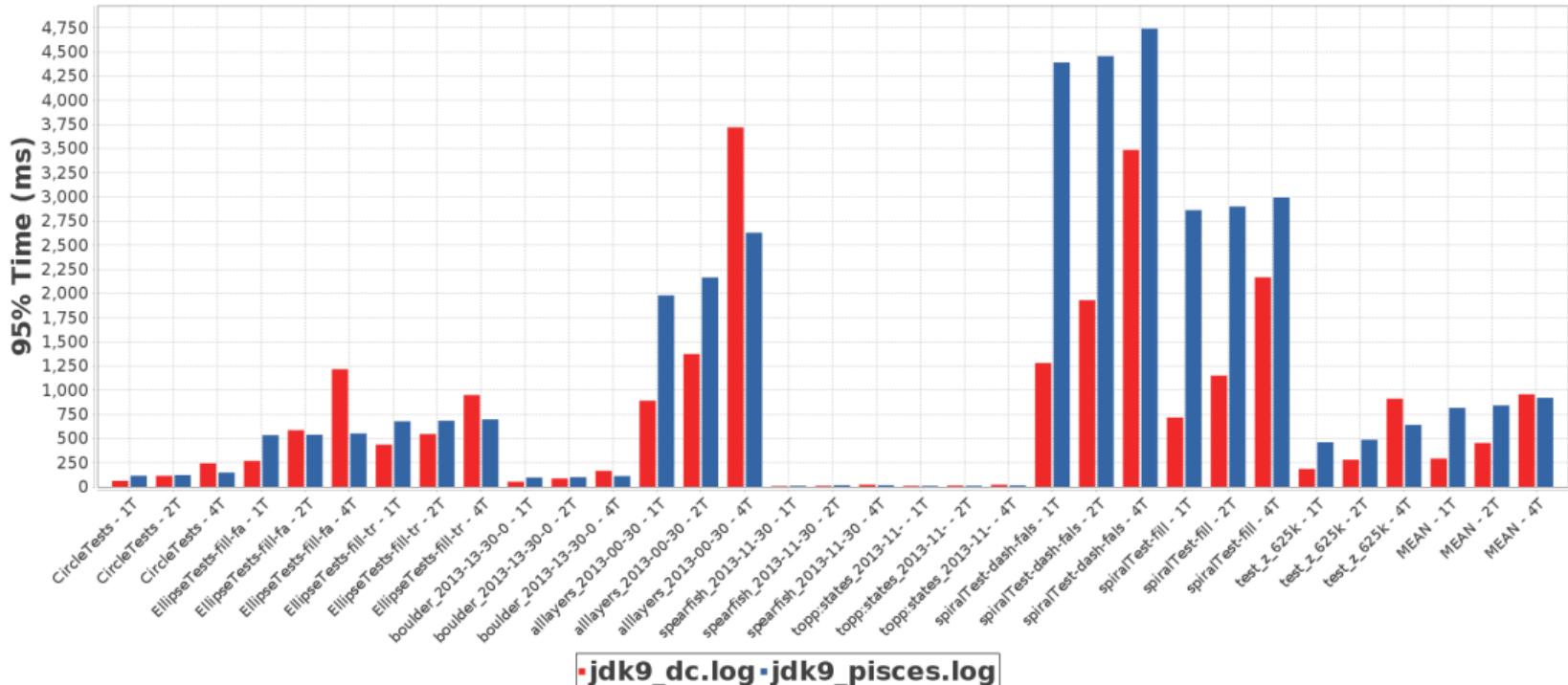
Marlin usage & benchmarks

Comparing AA renderers in JDK-9
(Ductus, Pisces, Marlin)

Before Marlin (Oracle JDK-9 EA b181)



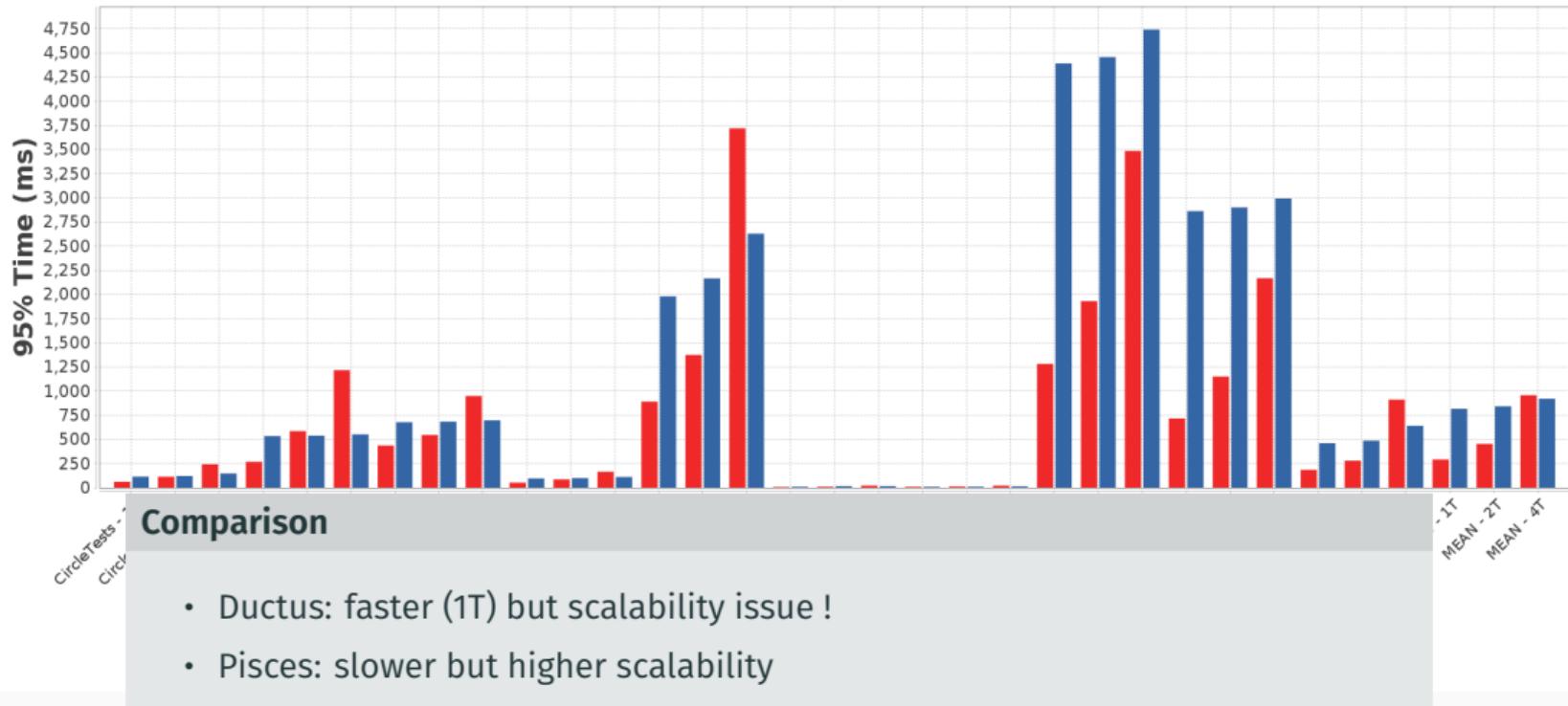
- Oracle JDK **Ductus** & **Pisces**



Before Marlin (Oracle JDK-9 EA b181)



- Oracle JDK **Ductus** & **Pisces**

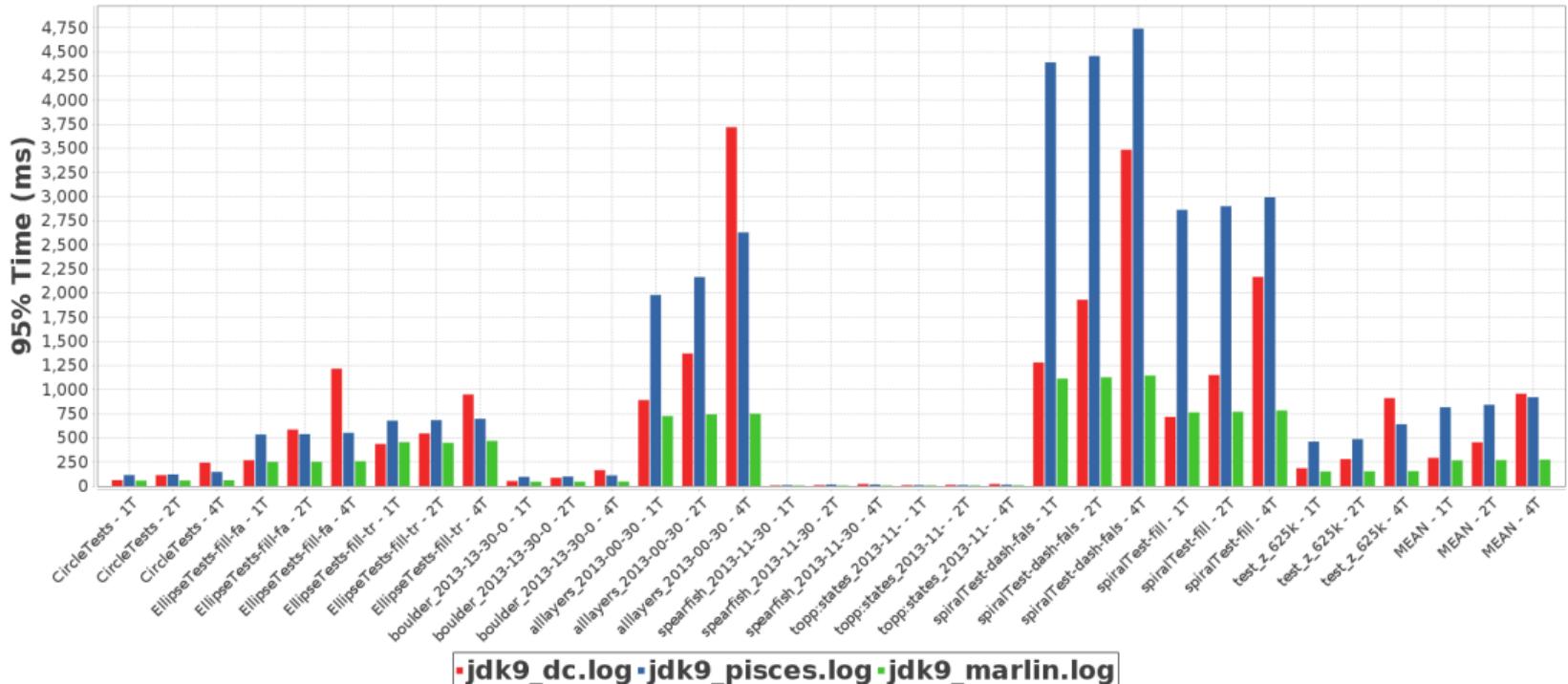


- Ductus: faster (1T) but scalability issue !
 - Pisces: slower but higher scalability

With Marlin (Oracle JDK-9 EA b181)



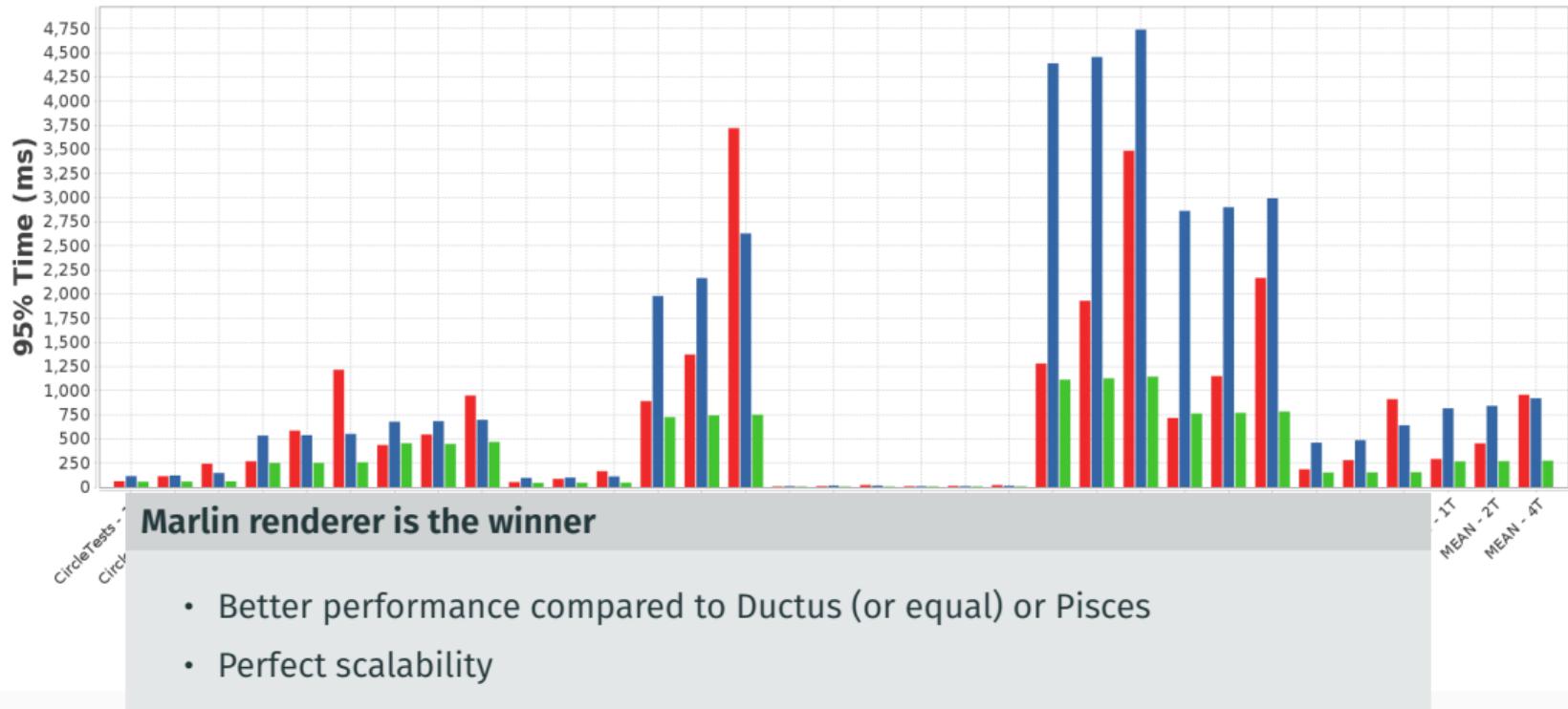
- Oracle JDK **Ductus** & **Pisces** & **Marlin**



With Marlin (Oracle JDK-9 EA b181)



- Oracle JDK **Ductus** & **Pisces** & **Marlin**

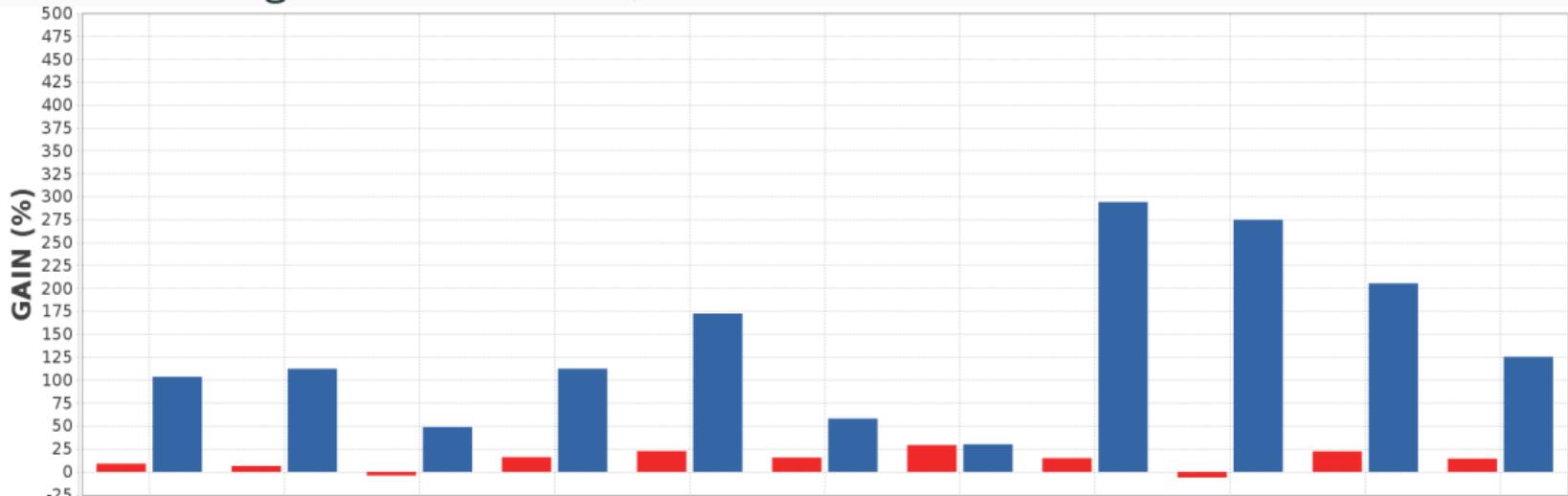


- Better performance compared to Ductus (or equal) or Pisces
 - Perfect scalability

Performance gains (1 thread)



- **Marlin** gains over Oracle JDK **Ductus** & **Pisces**



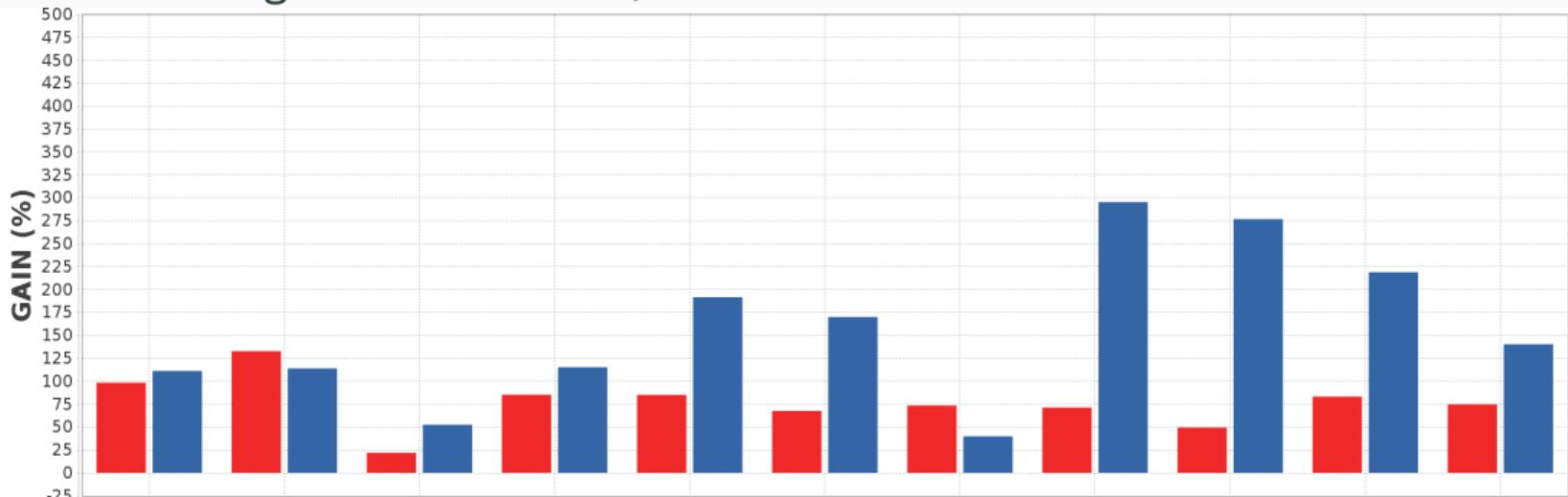
Marlin performance gains (single thread)

- vs Ductus: **10%** to **30%**
- vs Pisces: **125%** (average), up to **300%** (stroked spiral test)

Performance gains (2 thread)



- **Marlin** gains over Oracle JDK **Ductus** & **Pisces**



Marlin performance gains (2 threads)

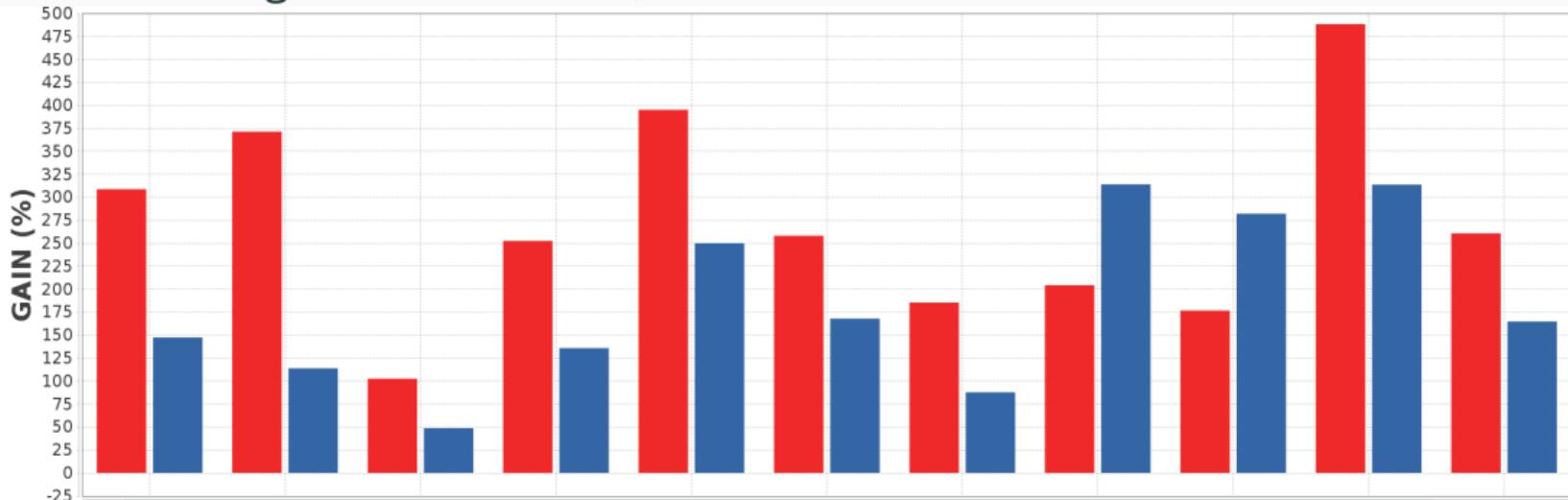
MEAN - 2T

- vs Ductus: **75%** (average)
- vs Pisces: **140%** (average)

Performance gains (4 thread)



- **Marlin** gains over Oracle JDK **Ductus** & **Pisces**



Marlin performance gains (2 threads)

CircleTe

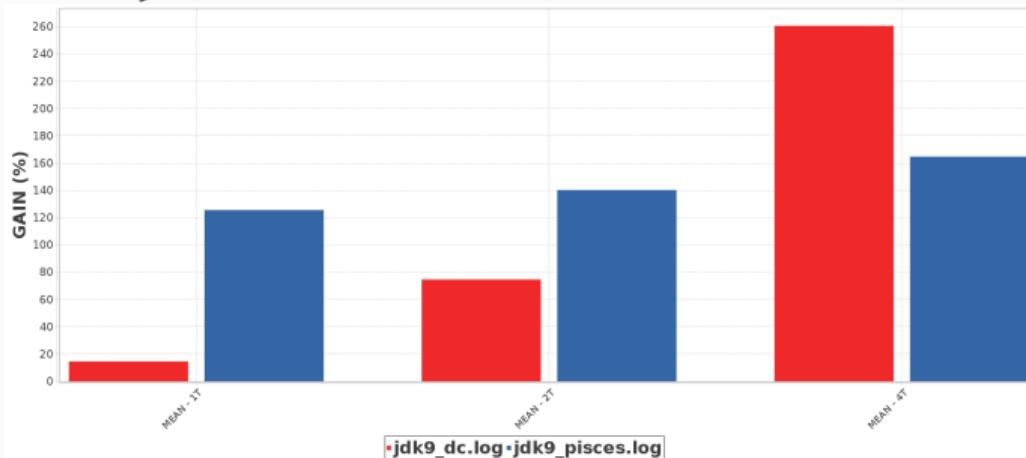
MEAN, 87

- vs Ductus: **250%** (average)
 - vs Pisces: **160%** (average)

Marlin Performance Summary (JDK-9)



- Compared to **Ductus** :
 - Same performance (1T) but better scalability up to 250% gain (4T)
- Compared to **Pisces** :
 - 2x faster: 100% to 150% gain
- Perfect scalability 1T to 4T



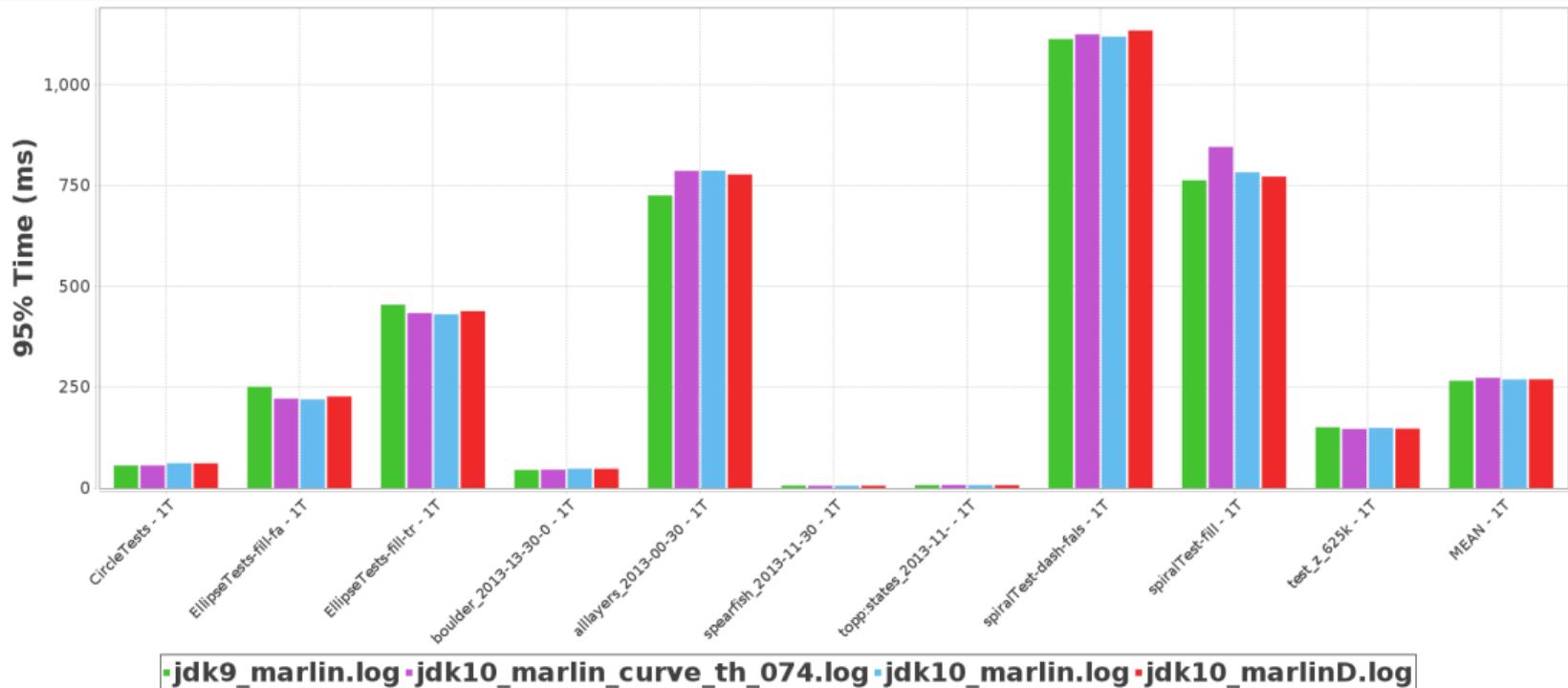
Marlin usage & benchmarks

**Comparing Marlin renderer changes
between JDK-9 & OpenJDK-10**

Marlin Performance changes (JDK-9 vs OpenJDK-10)



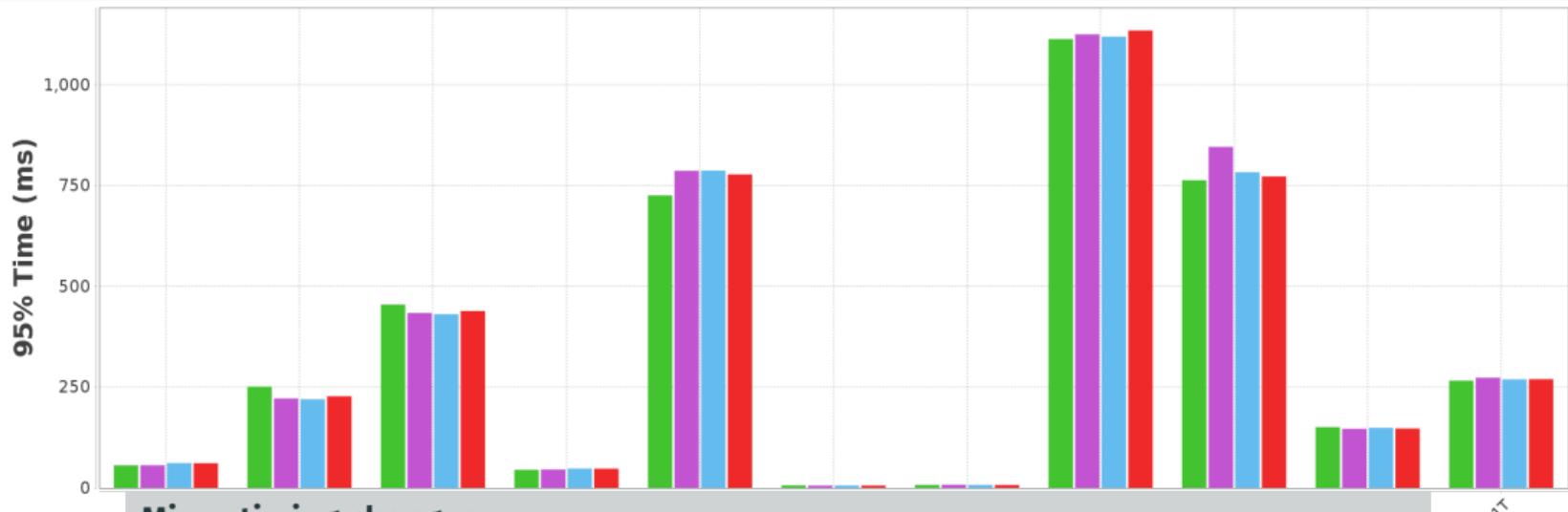
- Marlin 0.7.5 vs 0.7.4 (curve accuracy, large fills, Double variant)



Marlin Performance changes (JDK-9 vs OpenJDK-10)



- Marlin 0.7.5 vs 0.7.4 (curve accuracy, large fills, Double variant)



Minor timing changes

Circle

MEAN IT

- large fills: 10% faster (large ellipse tests)
- curves: 10% slower (lots of curves)

Marlin Performance Summary (JDK-9 vs OpenJDK-10)



- Marlin 0.7.5 vs 0.7.4 (curve accuracy, large fills, Double variant)



Same Marlin (average) performance in OpenJDK-10 as in JDK-9

MEAN +/-
STDEV

- Large fills are 10% faster, improved curve accuracy is only 10% slower
- No difference between Float and Double Marlin variants

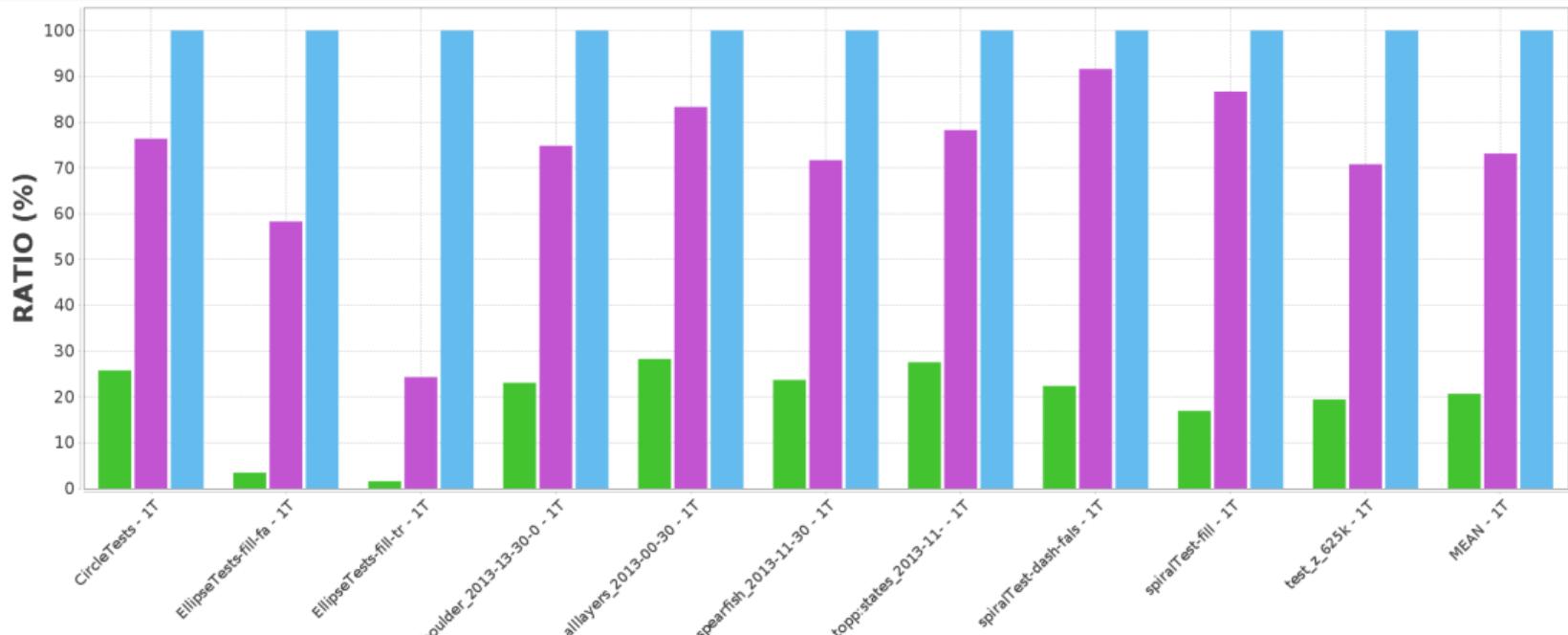
Marlin usage & benchmarks

Studying Marlin & Java2D internal stages

Marlin internal timings



- 3 stages in Java2D pipeline: Path Processing → Rendering → Blending

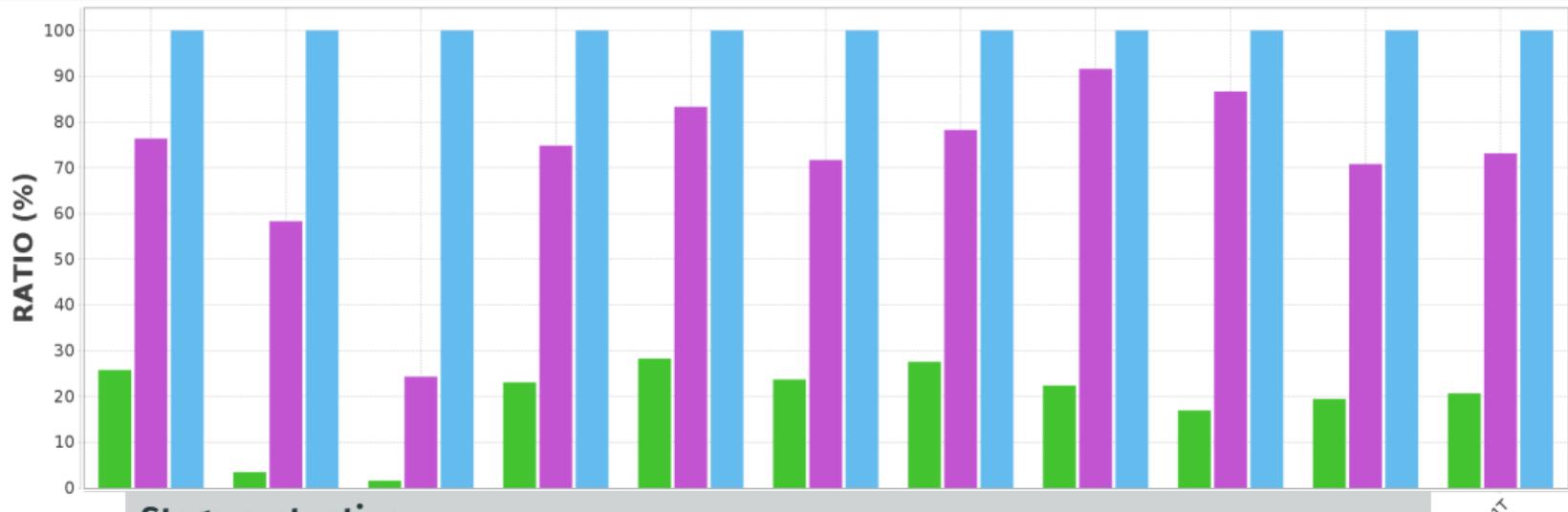


▪ `jdk8_marlin_no_render.log` ▪ `jdk8_marlin_no_blending.log` ▪ `jdk8_marlin_0811.log`

Marlin internal timings



- 3 stages in Java2D pipeline: Path Processing → Rendering → Blending



Stage cost ratios

- Path processing: 20 to 30% (stroked shapes) but 3% (filled)
- Blending: **25%** (average) but up to 75% (large ellipse fills): *Future work ?*

Marlin renderer tuning



Marlin can be customized by using system properties:

- adjust sub-pixel sampling:
 - X/Y=3: [8x8] (by default)
 - smaller values are faster but less accurate
 - higher values are slower but more accurate
- pixel sizing: typical largest shape width / height (2048 by default)
- adjust tile size: 6 [64x64] seems better than 5 [32x32]

Debugging:

- log statistics to know what happens
- enable checks if SEG faults or artefacts !

Marlin System properties



System property	Values	Description
-Dsun.java2d.renderer.<KEY>=		
useThreadLocal	true - false	RdrCtx in TL or CLQ (false)
useRef	soft - weak - hard	Reference type to RdrCtx
pixelsize	2048 in [64-32K]	Typical shape W/H in pixels
subPixel_log2_X	3 in [1-8]	Sub-pixel count on X axis
subPixel_log2_Y	3 in [1-8]	Sub-pixel count in Y axis
tileSize_log2	5 in [3-8]	Pixel width/height for tiles
doStats	true - false	Log rendering statistics
doChecks	true - false	Perform array checks
useLogger	true - false	Use j.u.l.Logger

Log-2 values for sub-pixel & tile sizes:



JDK-9 bug fixes from <http://bugs.openjdk.java.net>

- [JDK-6488522](#) **PNG writer** should permit setting compression level → **set compression level to medium [4 vs 9]**
- [JDK-8078464](#) **Path2D storage growth algorithms should be less linear**
- [JDK-8084662](#) Path2D copy constructors and clone method propagate size of arrays from source path
- [JDK-8074587](#) Path2D copy constructors do not trim arrays
- [JDK-8078192](#) Path2D storage trimming
- [JDK-8169294](#) JFX Path2D storage growth algorithms should be less linear

MarlinFX



2016: Port Marlin into JavaFX Prism engine

- <https://github.com/bourgesl/marlin-fx>
- **Prism integration:**
 - Only concerns complex paths (not ellipse or rounded rect., 3D meshes)
 - Complete mask, no more tiles
 - GPU back-end is faster but uploading texture may be costly
 - but single-threaded (GUI)
 - TBD: use Marlin to implement createStrokedShape()
- **Double-precision variant to improve accuracy** on very large shapes (stroke / dashes)
- **Integrated in OpenJFX-9** (dec 2016) but disabled by default

MarlinFX System properties



'sun.java2d.marlin' prefix → 'javafx.prism.marlin' prefix

TODO: complete

My feedback on contributing to OpenJFX



Contrary to Marlin, OpenJFX patches were more quickly integrated into OpenJFX-9 (Jim Graham, again) !

TODO: complete

MarlinFX usage & benchmarks

How to use MarlinFX ?



MarlinFX is available in all JDK-9 builds (Oracle, Zulu, Gluon):

- Enable MarlinFX using prism settings:

```
1 java -Dprism.marlinrasterizer=true ...
```

- Select Marlin Double or Float variant:

```
1 java -Dprism.marlinrasterizer=true -Dprism.marlin.double=true ...
```

- To enable the Prism log, add **-Dprism.verbose=true**:

```
1 Prism pipeline init order: es2
```

```
2 Using Marlin rasterizer (double)
```

DemoFX benchmarks



- OpenJFX-9 b146 first results with DemoFX Triangle test [VSYNC]

Vous avez retweeté

Chris Newland @chriswhocodes · 28 nov. 2016

The new MarlinFX rasterizer for #JavaFX in JDK9 EA b146 is fast and uses less memory! Awesome work by @laurent_bourges :)

À l'origine en anglais

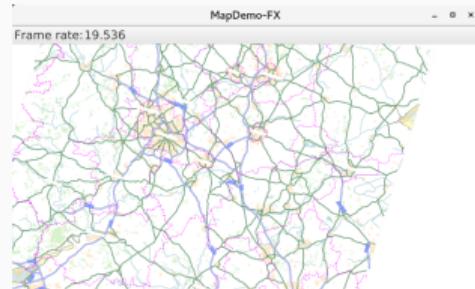
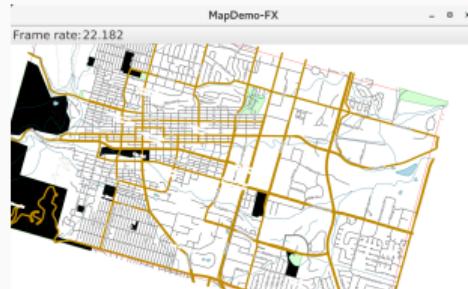
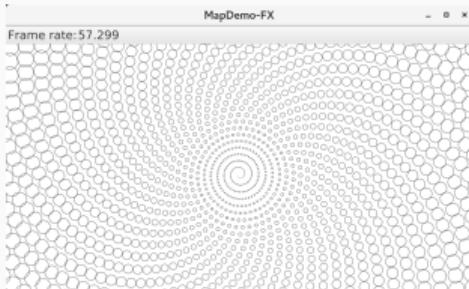
58 fps vs 48 fps = 20% gain

4 28 35

MapBenchFX benchmarks



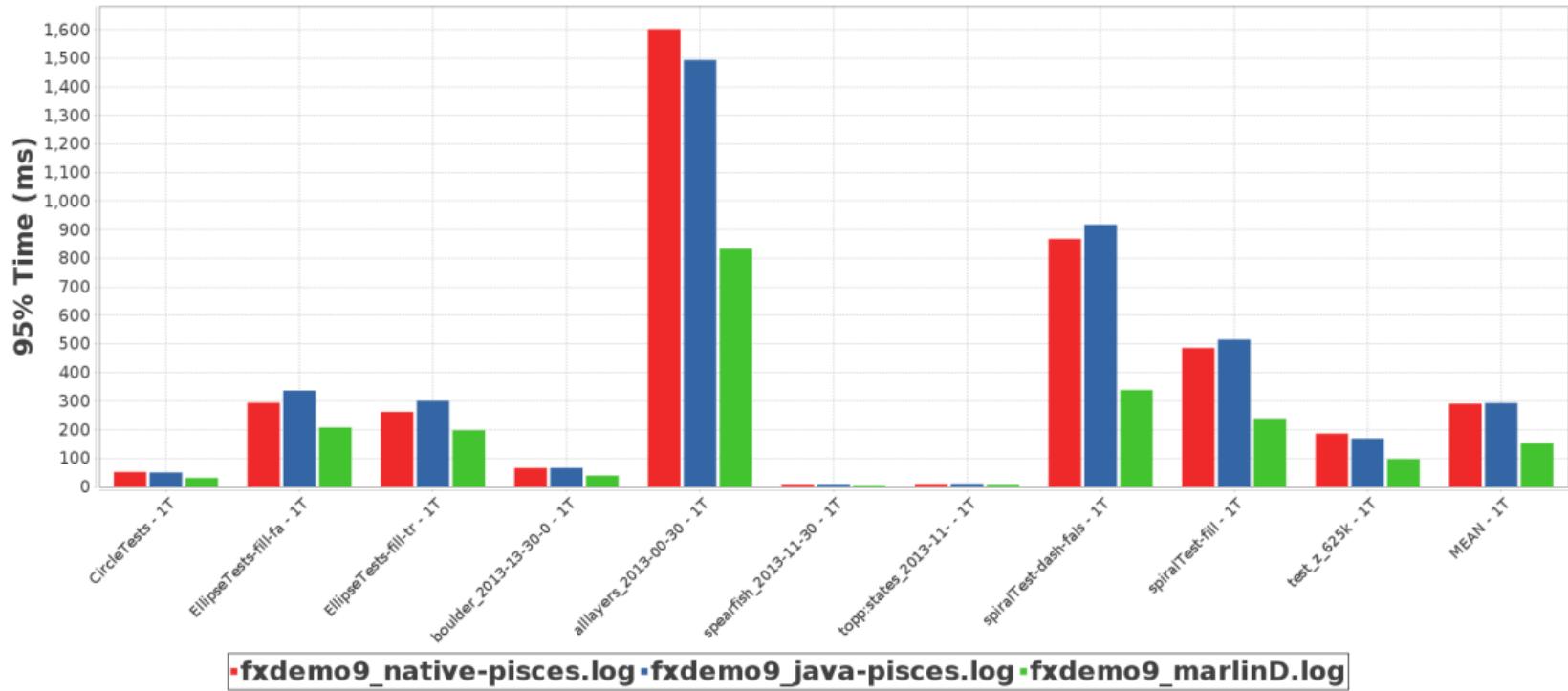
- **MapBenchFX**: JavaFX application to render maps
 - Port of the **Java2D MapBench benchmark** using FXGraphics2D
 - <https://github.com/bourgesl/mapbench-fx>



MarlinFX vs Native & Java Pisces (Oracle JDK-9 EA b181)



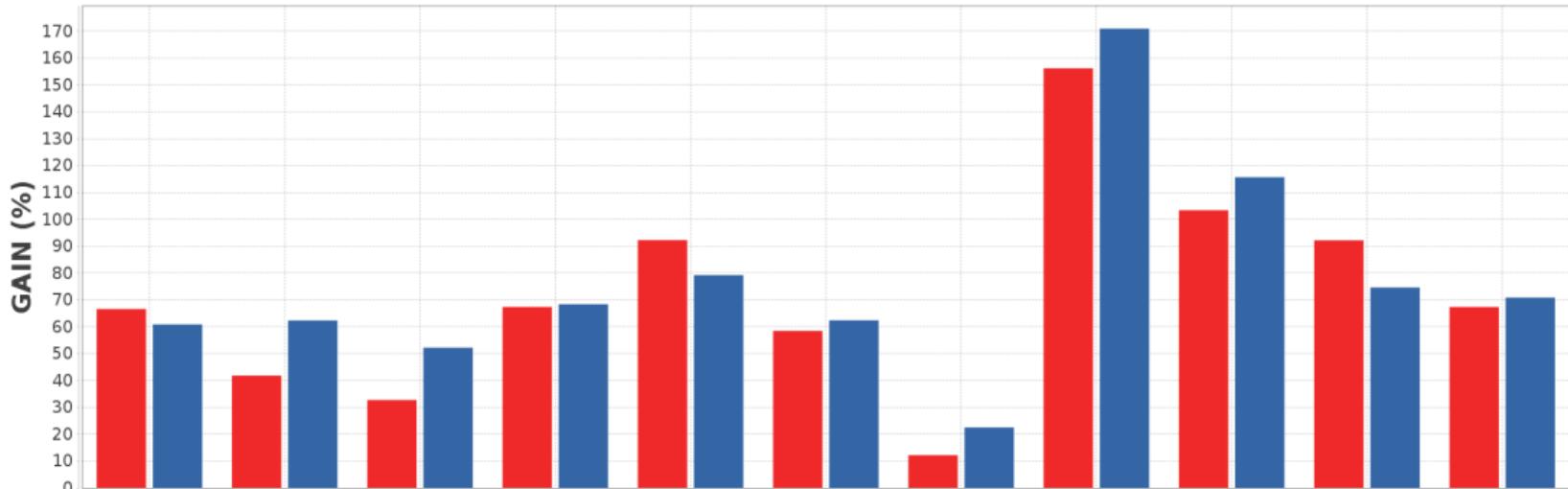
- Native Pisces & Java Pisces & MarlinFX



MarlinFX vs Native & Java Pisces (Oracle JDK-9 EA b181)



- MarlinFX gains over Native Pisces & Java Pisces



MarlinFX renderer is the winner (on linux)

- vs Native Pisces: **65%** (average)
 - vs Java Pisces: **70%** (average)

Perspectives and Future Work



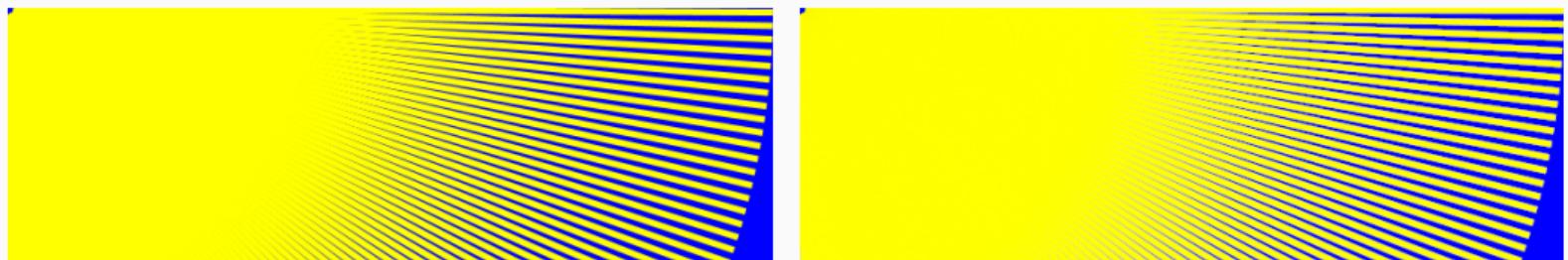
I may have still spare time to improve Marlin... **but no more alone !**

We want You = your help is needed:

- adopt the **Java Client** group
- **Try your applications** & use cases with the Marlin renderer
- **Contribute to the Marlin project**: let's implement new algorithms
(gamma correction, clipping ...)
- Provide **feedback**, please !



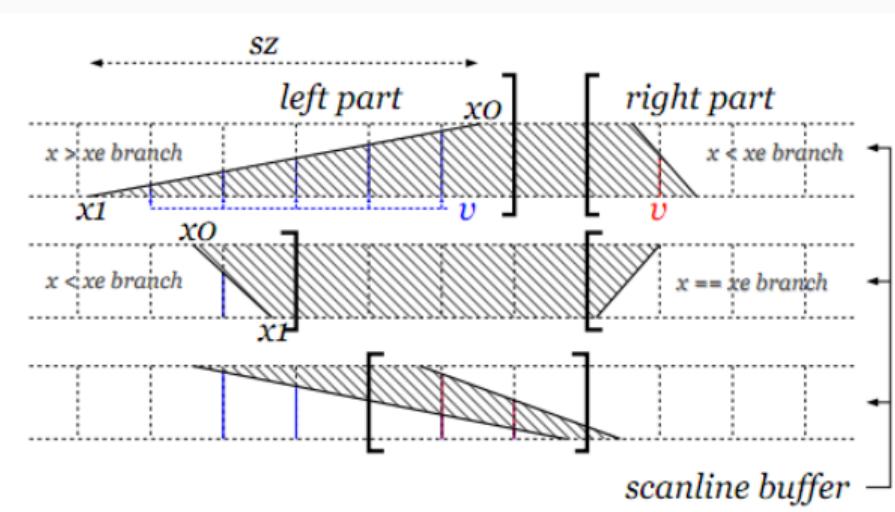
- Handle properly the gamma correction:
 - in MaskFill for images (C macros) & GPU back-ends
 - **Very important for visual quality**
 - note: Stroke's width must compensate the gamma correction to avoid having thinner / fatter shapes.





Quality Ideas (continued)

- **Analytical pixel coverage:** using signed area coverage for a trapezoid
⇒ compute the exact pixel area covered by the polygon





- **Clipping (coming in release 0.8):**
 - implement early efficient path clipping (major impact on dashes)
 - take care of affine transforms (margin), stroke's cap & joins
- **Cap & join processing (Stroker):**
 - do not emit extra collinear points for squared cap & miter joins
 - improve Polygon Simplifier ?
- **Scan-line processing (8x8 sub-pixels):**
 - 8 scan-lines per pixel row ⇒ compute exact area covered in 1 row
 - see algorithmic approach (AGG like):
<http://nothings.org/gamedev/rasterize/>
 - may be almost as fast but a lot more precise !

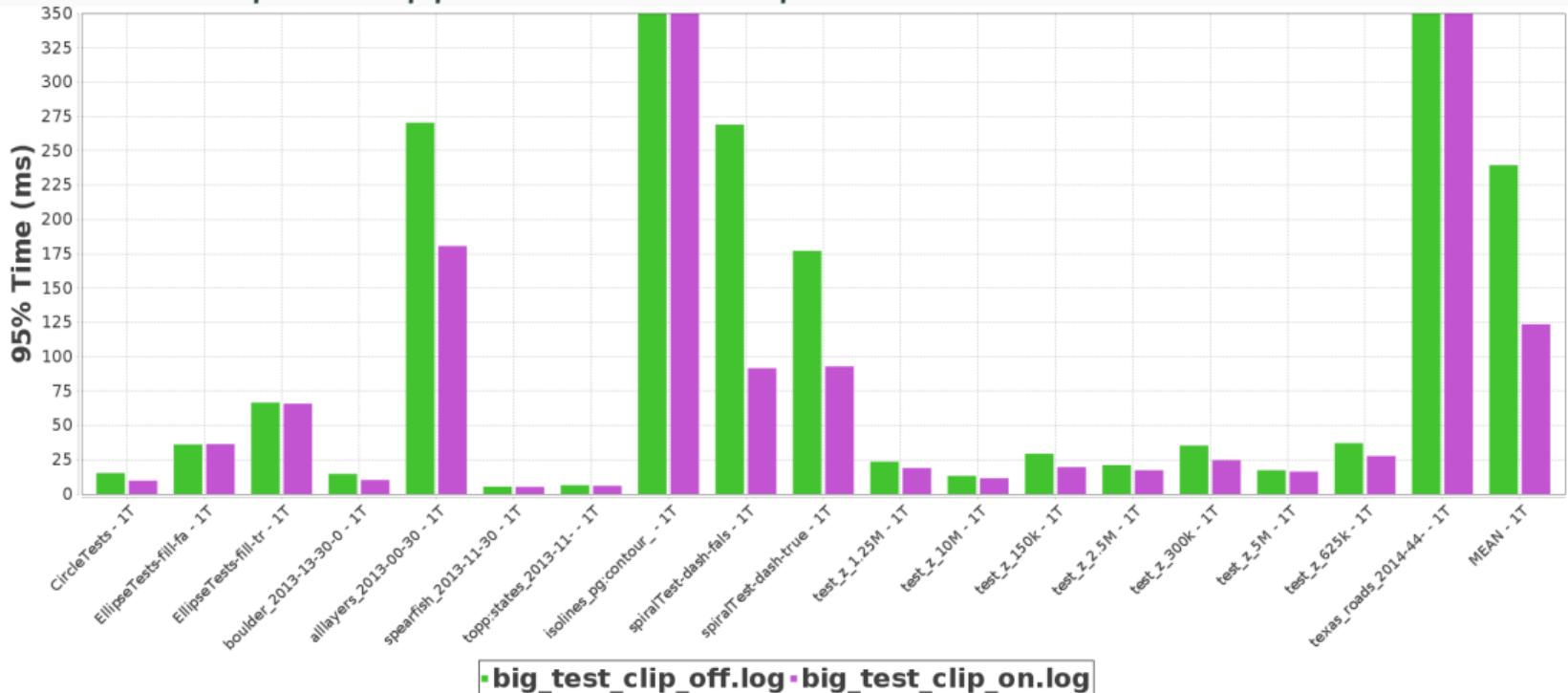
Perspectives and Future Work

**First results of the path clipping in
Marlin 0.8.1**

Performance impact of the path clipping (Marlin 0.8.1)



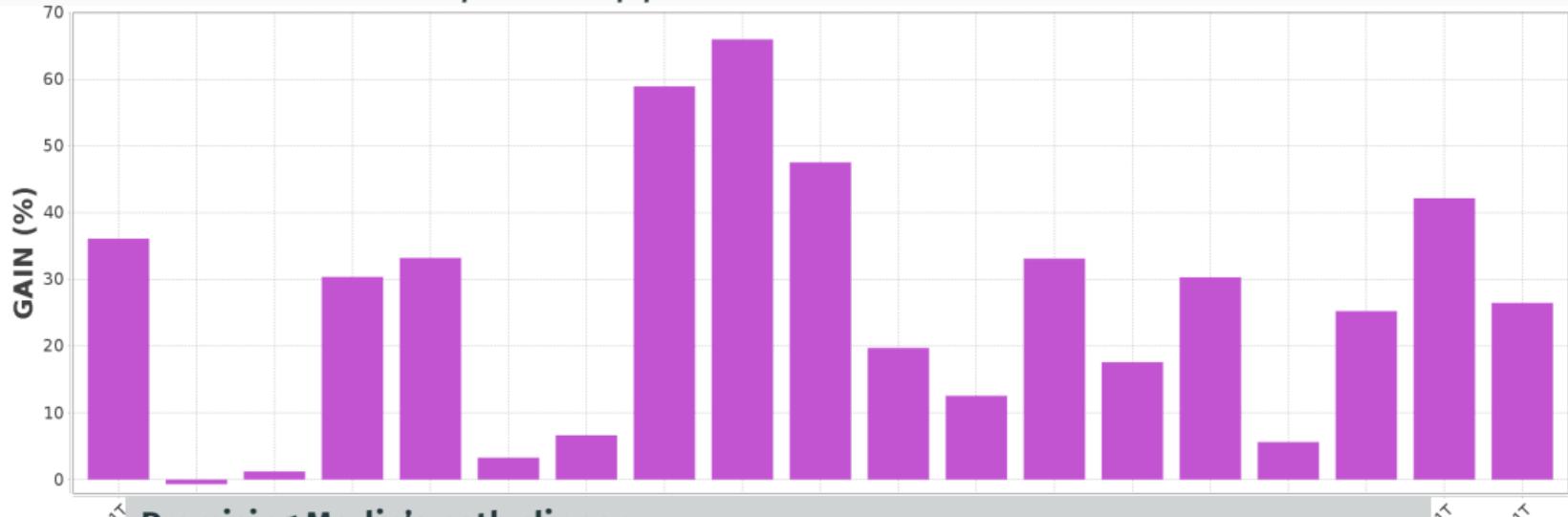
- Marlin path clipper Off vs On [clip 400 x 400]:



Performance impact of the path clipping (Marlin 0.8.1)



- Gain with Marlin path clipper enabled:



Promising Marlin's path clipper

- 25% gain (average)
- up to 65% gain (complex shapes)

Conclusion

Conclusion



- **Marlin renderer rocks in Java 9 !**
 - **Performance goals met**
 - **Scales for multiple threads** whereas Ductus does not
 - **Single threaded performance** generally **as good or better**
 - **Quality goals met**
- **Marlin is now the default AA renderer for Oracle JDK (and OpenJDK).**
- **MarlinFX will be the default renderer in OpenJFX-10**
- **Coming patches** are promising for **OpenJDK-10...**
- **What future for Java Client & Desktop ?**

That's all folks !



- Please ask your questions or talk with me
- or send them to marlin-renderer@googlegroups.com

Special thanks to:

- **Andréa Aimé & GeoServer team**
- **OpenJDK** teams for their help, reviews & support:
 - Jim Graham & Phil Race (Java2D)
 - Mario Torre & Dalibor Topic
 - Mark Reinhold
- ALL Marlin users



Special Thanks to all my donators:

- **GeoServer Project Steering Committee**
- **Gluon Software**
 - Thanks for all that you do to make JavaFX an awesome UI library
- **Dirk Lemmermann**
 - What would I do without people like you? So here you go!
- **AZUL SYSTEMS**
- **OpenJDK members:**
Mark Reinhold, Jim Graham, Phil Race, Kevin Rushforth
- **Manuel Timita**
 - Your work means a lot to us!
- H. K.



- **Andréa Aimé**

- Laurent helped solving a significant performance/scalability problem in server side Java applications using java2d. Let's help him reach JavaOne and talk about his work!

- **Chris Newland**

- Laurent has made a big contribution to OpenJDK with his Marlin and Marlin-FX high performance renderers. Let's help him get to JavaOne 2017!

- **Simone Giannecchini**

- Brad Hards

- Z. B.

- Mario Ivanka

- **JUGS e.V.**

- Peter-Paul Koonings (GeoNovation)

JavaOne Sponsors (gofundme)



- Michael Paus
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- Chris Holmes
- Michael Simons
- P. S.
- A. B.
- Igor Kolomiets
- Vincent Privat

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- Carl Dea
 - I'm not going to JavaOne, but hearing about Laurent Bourgès making Java 2D faster caught my attention. Graphics and performance engineers are true heroes. They make users of the APIs look good, while their work under the covers really do the heavy lifting. Go Laurent!
- Mike Duigou
 - Would love to see JavaOne sponsor opensource committers in future years
- M. H.
- J. M.

Extra

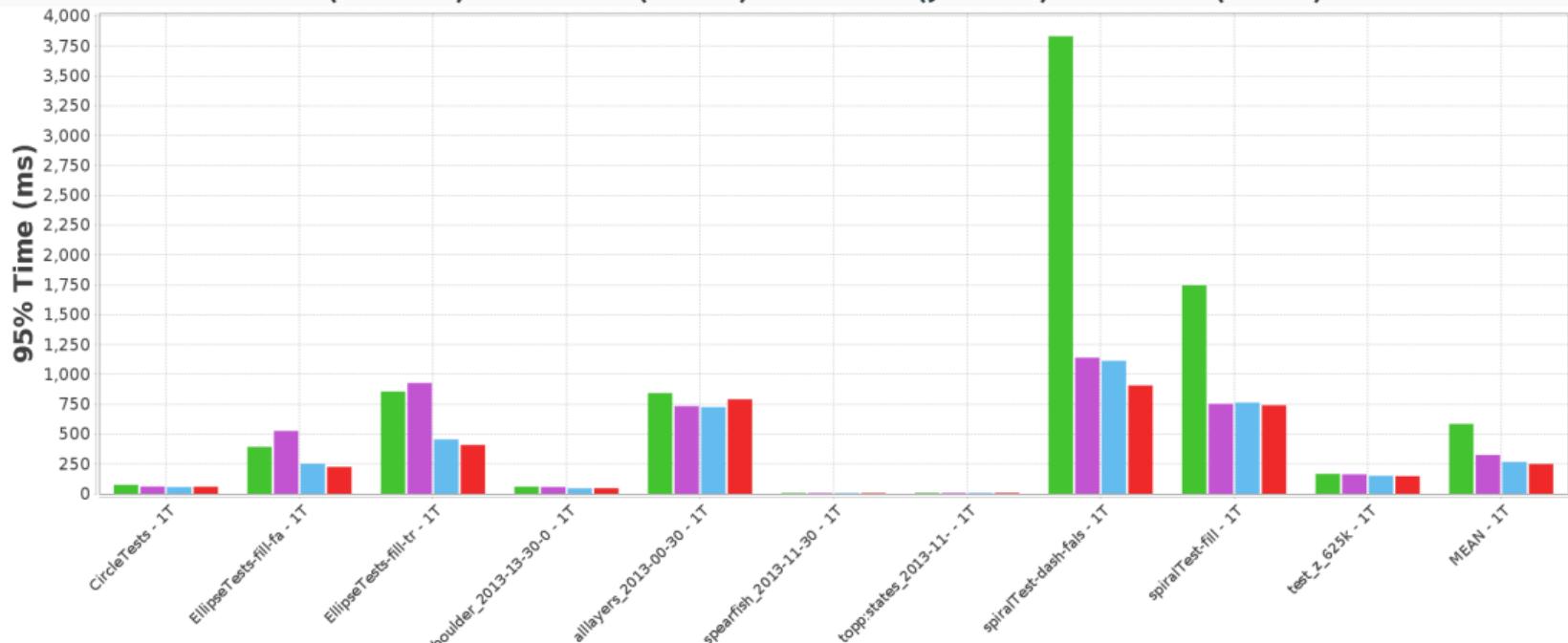
Extra

**Comparing Marlin renderer releases
using JDK-8**

Performance evolution between Marlin 0.3 & 0.8.1 (JDK-8)



- Marlin 0.3 (2014.1) & 0.5.6 (2015) & 0.7.4 (JDK-9) & 0.8.1 (2017)

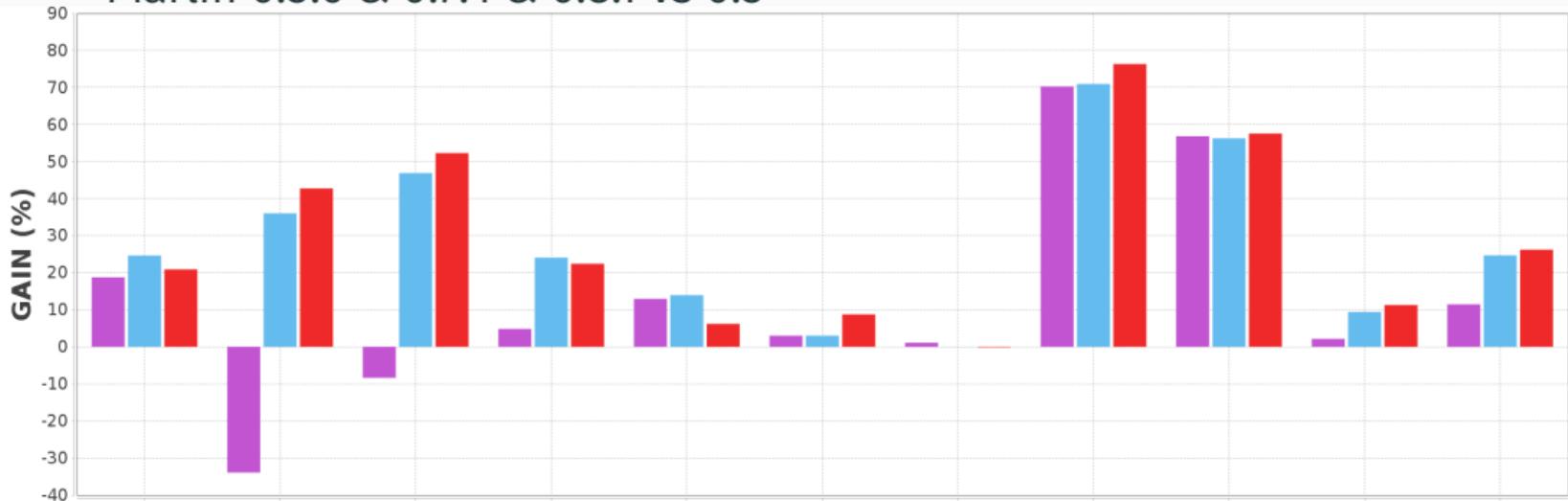


[jdk8_marlin_03.log](#) • [jdk8_marlin_056.log](#) • [jdk9_marlin.log](#) • [jdk8_marlin_0811.log](#)

Performance evolution between Marlin 0.3 & 0.8.1 (JDK-8)



- Marlin 0.5.6 & 0.7.4 & 0.8.1 vs 0.3



Marlin performance improved through releases

- Loss in 0.5.6 (large ellipse fills) fixed in 0.7
- Important improvements on complex stroked shapes (spirals)

MEAN - IT

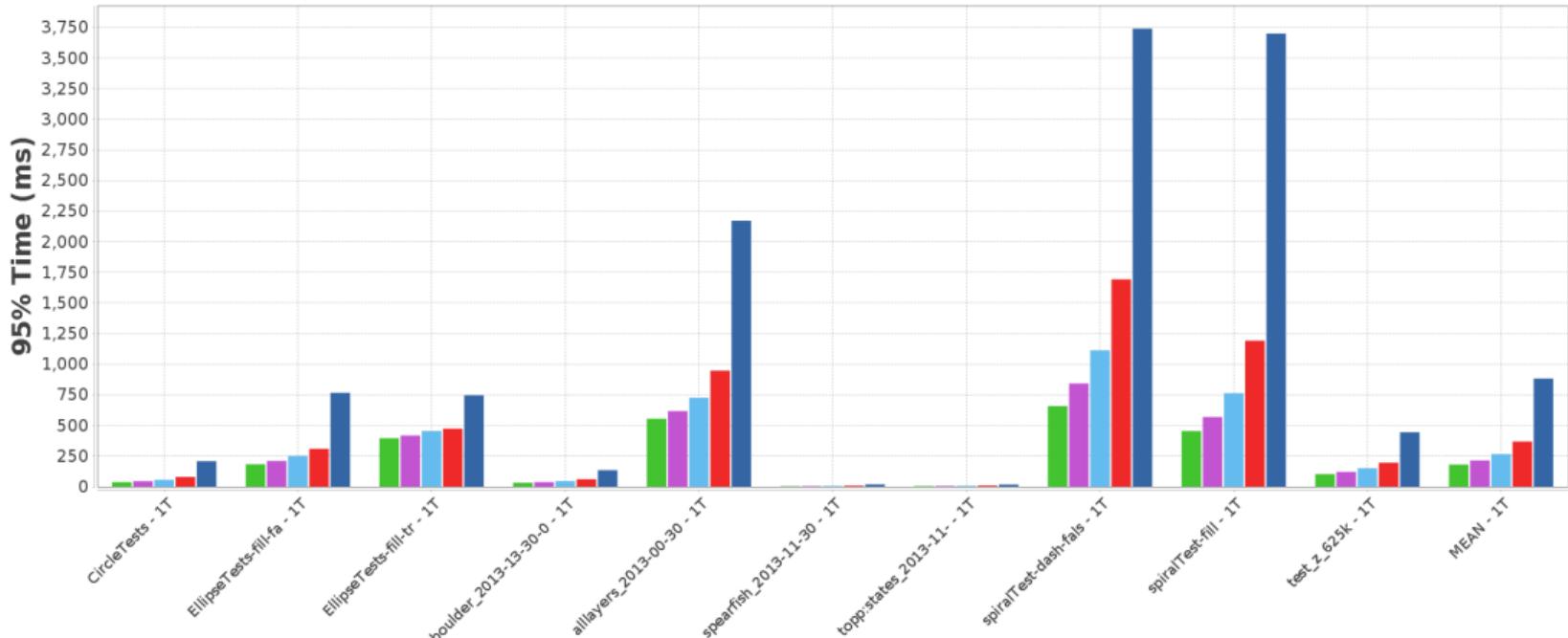
Extra

**Performance impact of the sub-pixel
tuning**

Performance impact of the sub-pixel tuning



- Sub-pixel settings [1x1 to 6x6]:



[jdk9_marlin_sp1.log](#) • [jdk9_marlin_sp2.log](#) • [jdk9_marlin.log](#) • [jdk9_marlin_sp4.log](#) • [jdk9_marlin_sp6.log](#)

Performance gain & loss of the sub-pixel tuning



- Gain & Loss of Sub-pixel settings [1 x 1 to 6 x 6] VS [3 x 3]:

