

User Manual 4.4 Math frameworks

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Introduction

Scope

This section describes PATRIUS handling of low-level math frameworks. A low-level math framework provides simple math operations such as sin, cos, exp, etc. Before PATRIUS 4.2, the only existing framework is `FastMath`. Since version 4.2, the notion of math framework has been generalized and the user can use various framework:

- `FastMath`
- `Math`
- `StrictMath`
- JAFAMA 2.3.1 `FastMath`
- JAFAMA 2.3.1 `StrictFastMath`
- An implementation corresponding for each function to fastest implementations among all above libraries.
- Its own defined framework

JAFAMA is a fast open-source Math library. To be usable in PATRIUS, a dependency to JAFAMA 2.3.1 has been added in PATRIUS pom.xml file.

Javadoc

The math framework classes are available in the package `fr.cnes.sirius.patrius.math.framework`.

Library

Javadoc

Patrius [Package fr.cnes.sirius.patrius.math.framework](#)

Links

One of the framework available is JAFAMA. JAFAMA is an open-source library under Apache 2.0 licence. More information can be found at <https://github.com/jeffhain/jafama>

Useful Documents

None as of now.

Package Overview

Features Description

Features

A low-level Math framework is a class implementing all the original `FastMath` functions (sin, exp, min, atan, etc.). All low-level Math framework should implement the `MathLibrary` interface. Currently there are three implementations of the `MathLibrary` interface:

- `FastMathWrapper` which is a wrapper for `FastMath` static class.
- `MathWrapper` which is a wrapper for `Math` static class.
- `StrictMathWrapper` which is a wrapper for `StrictMath` static class.
- `JafamaFastMathWrapper` which is a wrapper for JAFAMA `FastMath` static class.
- `JafamaStrictFastMathWrapper` which is a wrapper for JAFAMA `StrictFastMath` static class.
- `FastestMathLibWrapper` which is a wrapper for fastest math library among the listed above. Fastest functions are mainly Jafama `FastMath` functions except for simple functions (abs, ceil, floor, round, etc.) for which `FastMath` or `StrictMath` are faster.

The user can also define its own low-level Math framework by providing its own implementation of the `MathLibrary` interface.

Then in order to use the chosen low-level Math framework, the user must use the static class `MathLib`:

- By first defining the Math framework to use with methods `MathLib.setMathLibrary()` if different from `FastMath`.
- By then using the `MathLib` functions like the `FastMath` functions: `MathLib.sin(...)`

Note: by default, `FastMath` is set as the low-level Math library. Note 2: inner `PATRIUS` functions call `MathLib` which by default call `FastMath`. Hence there is strictly no numerical differences between use of `PATRIUS` 4.2 or older versions of `PATRIUS`.

When the user defines a low-level math framework then all `PATRIUS` operations are performed using this framework.

Performances of available Math framework

Computation times

Here are displayed computation time gains with using JAFAMA library (reference: `FastMath`).

| Item | Jafama <code>FastMath</code> | Jafama <code>StrictFastMath</code> |
|-------------------------------|------------------------------|------------------------------------|
| Numerical propagation | ≈ -10% | ≈ -10% |
| Analytical propagation | ≈ -30% | ≈ -30% |
| Attitude computation | ≈ -10% | ≈ -10% |

Note: these are averaged orders of magnitude and may vary from one case to another.

Accuracy

As stated in JAFAMA website, relative accuracy of operations is $1E-15$ (no regression would required a relative accuracy better than $1E-16$). As a result, use of `PATRIUS` with JAFAMA will lead to slightly different results. This will not occur on all operations.

Here are displayed absolute/relative error for standard `PATRIUS` uses with using JAFAMA library

(reference: FastMath).

| Item | Jafama | FastMath | Jafama | StrictFastMath |
|--|---------------|-----------------|---------------|-----------------------|
| Framework functions | | <1E-15 rel. | | <1E-15 rel. |
| Low-level space mechanics functions | | <1E-15 rel. | | <1E-15 rel. |
| LEO propagation on 24h | | <1E-6m | | <1E-6m |
| GEO propagation on 24h | | <1E-5m | | <1E-5m |
| GTO propagation on 24h | | <1E-6m | | <1E-6m |

Roughly, an absolute accuracy on position of 1E-6m for LEO orbits means a relative accuracy of 1E-12.

The accuracy (with respect to FastMath) is directly correlated to the number of used JAFAMA operations. To get an idea of what accuracy to expect:

- 1 single JAFAMA operation leads to a relative accuracy of 1E-15 or better
- 1 propagation over 24 h (with millions calls to JAFAMA) leads to a relative accuracy of 1E-12
 - Warning: **Except for StrictMath, PATRIUS does not guarantee implementations of various JVM will return the exact same result.

Getting Started

In the following section are defined potential use of Math framework.

Simple user

This user does not want to change anything with PATRIUS 4.2 upgrade. He has two options:

- Continue to use FastMath and do nothing in particular:

```
final double y = FastMath.sin(x);
```

- Still use FastMath through the use of MathLib

```
final double y = MathLib.sin(x);
```

Note: by default, MathLib calls FastMath.

Intermediate user

This user wants to use another Math framework (here FastMath from JAFAMA):

```
MathLib.setMathLibrary(MathLibraryType.JAFAMA_FASTMATH);  
final double y = MathLib.sin(x);
```

Advanced user

This user wants to use his own math framework:

```

final MathLibrary myOwnFramework = new MathLibrary() {
    public double sin(final double x) {
        return ...;
    }
    ...
}
MathLib.setMathLibrary(myOwnFramework);
final double y = MathLib.sin(x);

```

Contents

Interfaces

The library defines the following interfaces related to math frameworks:

| Interface | Summary | Javadoc |
|--------------------|--|---------------------|
| MathLibrary | Interface for low-level Math framework | ... |

Classes

The library defines the following classes related to low-level Math frameworks:

| Class | Summary | Javadoc |
|------------------------------------|--|---------------------|
| MathLib | Static class for generic low-level math functions use | ... |
| MathLibraryType | Enumeration for currently available Math framework in PATRIUS | ... |
| FastMathWrapper | Wrapper of FastMath class implementing MathLibrary interface | ... |
| MathWrapper | Wrapper of Math class implementing MathLibrary interface | ... |
| StrictMathWrapper | Wrapper of StrictMath class implementing MathLibrary interface | ... |
| JafamaFastMathWrapper | Wrapper of Jafama FastMath class implementing MathLibrary interface | ... |
| JafamaStrictFastMathWrapper | Wrapper of Jafama StrictFastMath class implementing MathLibrary interface | ... |
| FastestMathLibWrapper | Implementation wrapping the fastest implementation among Math, FastMath, StrictMath and Jafama for each function | ... |
| FastMath | Original class from PATRIUS providing low-level math functions | ... |

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