The learning outcome of this practical session is to rely on parallel streams to accelerate the computation of pi, a CPU-bound application.

1 Pi Computation

The value of \( \pi \) is estimated by sampling random points in the square defined by the coordinates \((0, 0)\) and \((1, 1)\), and by counting how many are in the circle of radius 1 and which center is \((0, 0)\). This value divided by the number of samples and by 4 approximates \( \pi \). This approach is called the Monte Carlo method: it consists in sampling \( n \) points and averaging the results.

Even though the class Random can directly give a stream (see https://docs.oracle.com/en/java/javase/19/docs/api/java.base/java/util/Random.html), it cannot be used directly to produce pairs of random values.

Write a stream implementation of this algorithm using generate and Math.random.

2 Parallel Version

To compare the performance of the sequential stream to the parallel one, it is necessary to select the number of samples \( n \) for the measurements. The selected number of samples should be high enough to prevent the initialization from being preponderant, but small enough to avoid wasting time waiting for a result. Find a value \( n \) that leads to a sequential execution of a few seconds (less than 5).

Measure precisely the time of the sequential execution of this implementation and its parallel execution to determine the speed-up (ratio of sequential time to parallel time).

Discuss and explain the measured performance relatively to the architecture and its potential for parallelization (use lscpu to determine the number of processors, cores and whether hyperthreading is enabled). Note that Math.Random is thread-safe.

Adapt the random generation by using ThreadLocalRandom instead of Math.random (see https://docs.oracle.com/en/java/javase/19/docs/api/java.base/java/util/concurrent/ThreadLocalRandom.html. What is the new speed-up (perform each measurement multiple times, especially when the durations are short)?

3 Custom Spliterator

We will implement a spliterator that replaces both methods generate and limit: it will convey the size of the stream, which will improve the performance (limit will not introduce the SIZED flag).

Implement a custom spliterator by redefining the methods tryAdvance, trySplit, estimateSize, and characteristics. The class StreamSupport can create a stream with a custom spliterator.

Compare the performance obtained with this custom to the performance with the direct approach with generate.