STRUCTURED CONCURRENCY WITH PROJECT LOOM

SARIKA SINHA

IBM

ECLIPSE PLATFORM & JDT CO-LEAD

AGENDA

- What is Project Loom all about?
- Difference between Threads and Virtual Threads
- How to use Virtual threads to implement concurrency on a finer-grained level than threads
- Using Deadlines to stop the running tasks
- Debugger Support for virtual threads

PROJECT LOOM

- High-throughput lightweight concurrency achieved by simpler constructs
  - Delimited Continuations
  - Virtual Threads
  - Tail-call elimination

TAIL-CALL ELIMINATION

A recursive function is tail recursive when a recursive call is the last thing executed by the function

Tail-call elimination is a compile-level optimization that is aimed to avoid stack overflow when calling a recursive method.

Tail-call elimination support in Java is still a future work

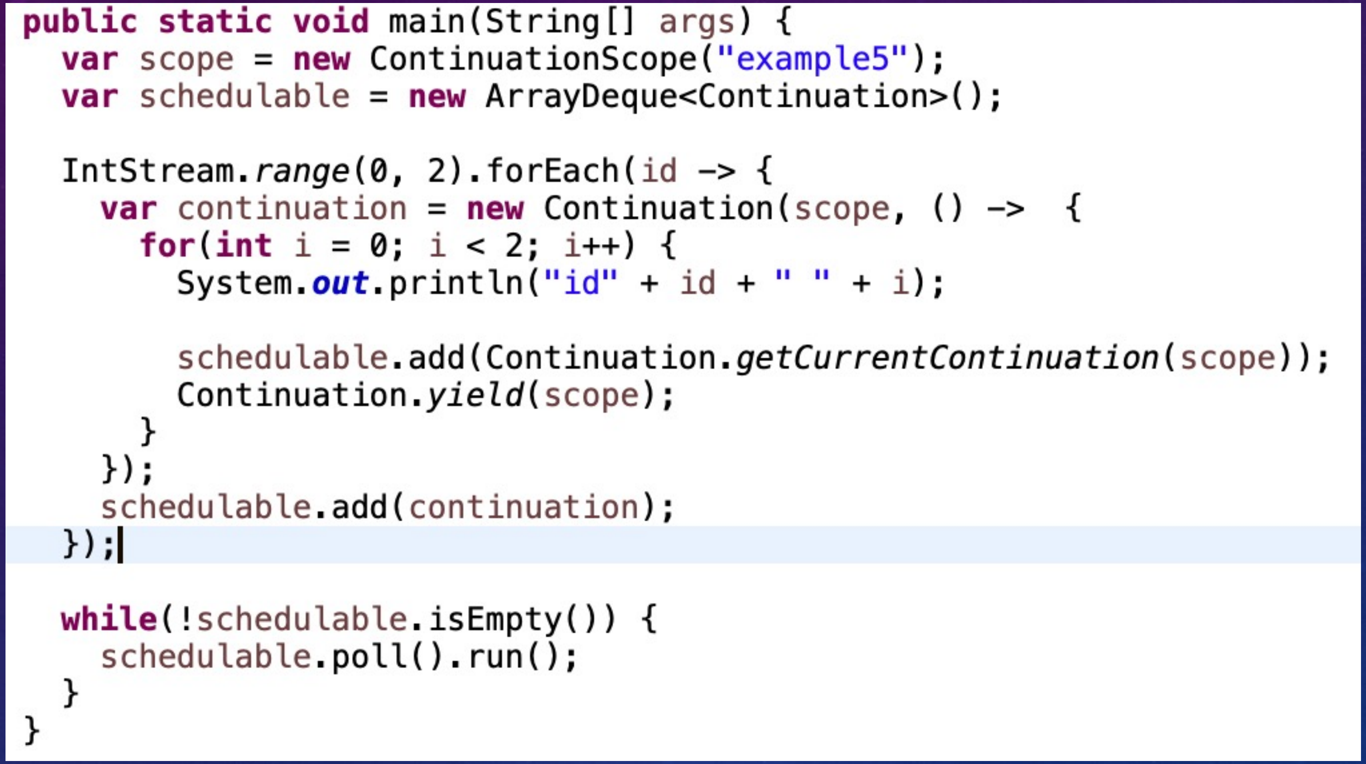
DELIMITED CONTINUATION

A Continuation (similar to coroutine) is a stack of function calls

It can be stopped and stored in the heap at some point (with yield) and restarted afterward (with run).

A continuation has no scheduler, so you have to write your own.

CONTINUATION EXAMPLE



```
public static void main(String[] args) {
  var scope = new ContinuationScope("example5");
  var schedulable = new ArrayDeque<Continuation>();

  IntStream.range(0, 2).forEach(id -> {
    var continuation = new Continuation(scope, () ->  {
      for(int i = 0; i < 2; i++) {
        System.out.println("id" + id + " " + i);

        schedulable.add(Continuation.getCurrentContinuation(scope));
        Continuation.yield(scope);
      }
    });
    schedulable.add(continuation);
  });

  while(!schedulable.isEmpty()) {
    schedulable.poll().run();
  }
}
```

VIRTUAL THREAD

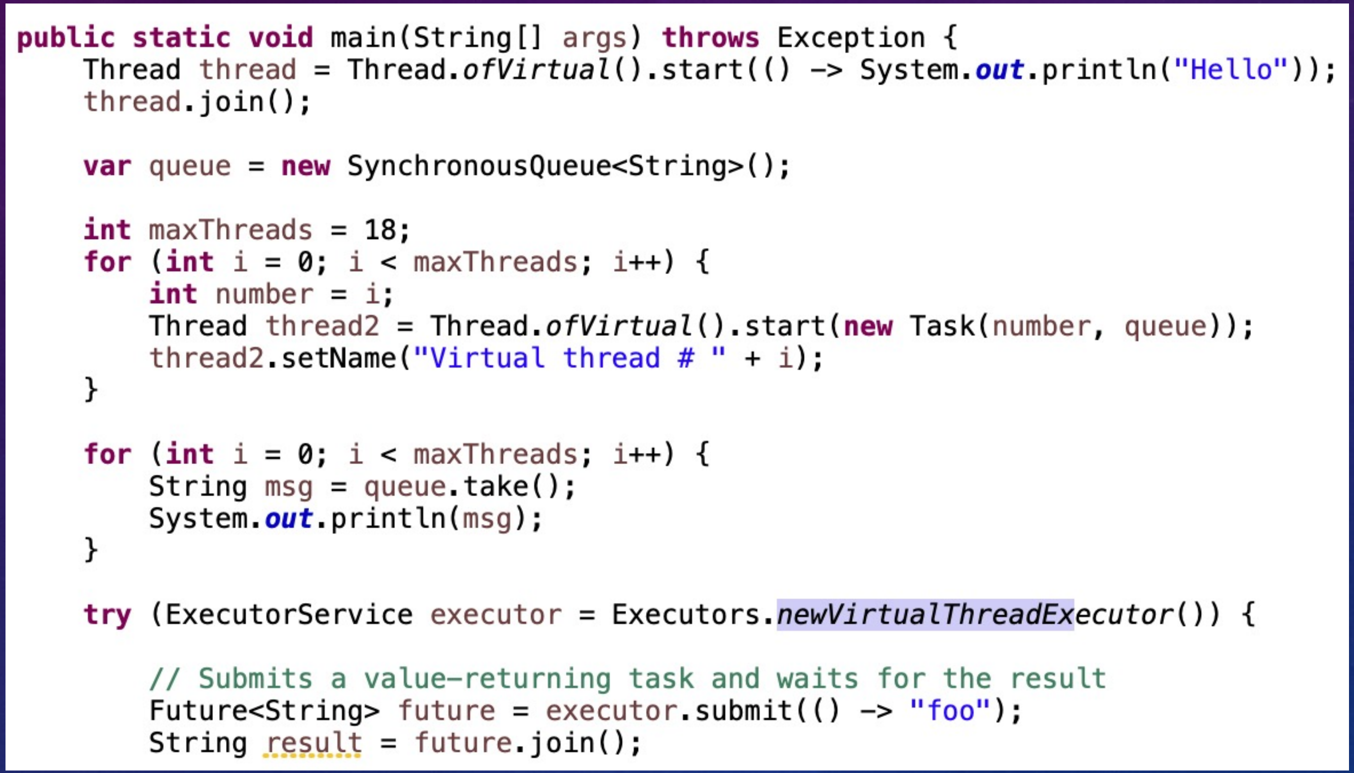
Virtual threads(Fibre) are just threads that are scheduled by the Java virtual machine rather than the operating system

- Normal Priority
- Daemon Threads
- No permissions with Security Manager
- Inactive threads in a thread group
- No support from Thread suspend, resume and stop APIs.

STRUCTURED CONCURRENCY

- Main task splits into several concurrent tasks
- Spawning threads must terminate before the main thread
- Executors API to create an ExecutorService that starts a new virtual thread for each task.
  - ExecutorServices API Executors.newVirtualThreadExecutor()
- ExecutorService defines submit methods to execute tasks for execution. The submit methods don't block, instead they return a Future object that can be used to wait for the result or exception.
- No impact on ForkJoinPool APIs

VIRTUAL THREAD EXAMPLE

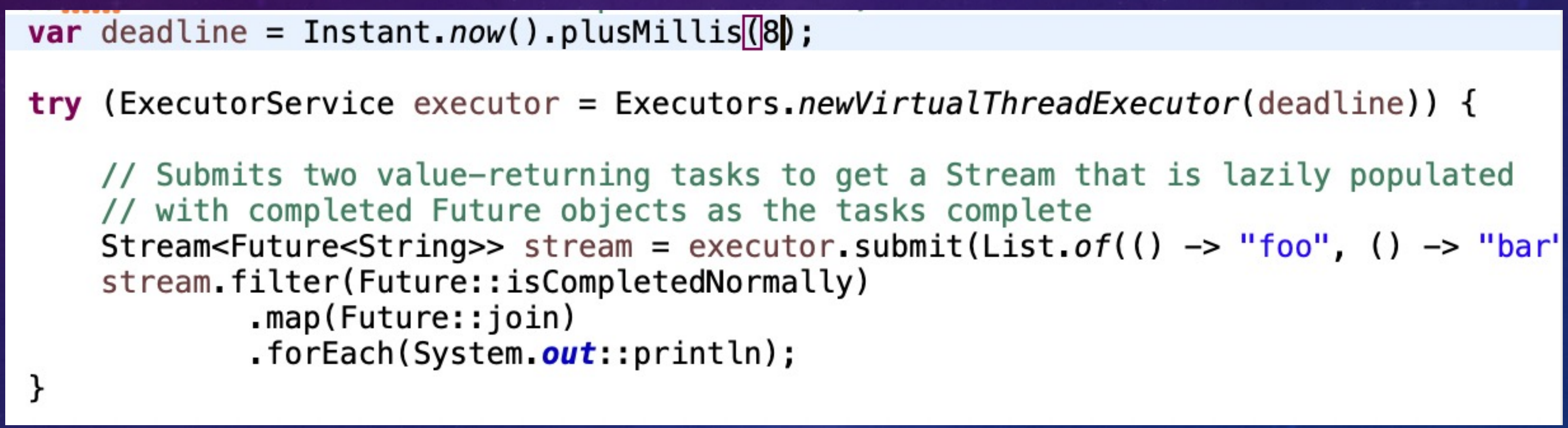


```java
public static void main(String[] args) throws Exception {
    Thread thread = Thread.ofVirtual().start(() -> System.out.println("Hello"));
    thread.join();

    var queue = new SynchronousQueue<String>();

    int maxThreads = 18;
    for (int i = 0; i < maxThreads; i++) {
        int number = i;
        Thread thread2 = Thread.ofVirtual().start(new Task(number, queue));
        thread2.setName("Virtual thread # " + i);
    }

    for (int i = 0; i < maxThreads; i++) {
        String msg = queue.take();
        System.out.println(msg);
    }

    try (ExecutorService executor = Executors.newVirtualThreadExecutor()) {

        // Submits a value-returning task and waits for the result
        Future<String> future = executor.submit(() -> "foo");
        String result = future.join();
```

DEADLINES

- Instead of saying that the Continuation scope is cancellable, we can give it a deadline and say that we are only willing to wait up until that deadline for any of the threads.
- An *ExecutorService* can be wrapped with a deadline
  - Executors.newVirtualThreadExecutor(Instant deadline)
- The deadline can expire before the executor has terminated
- Deadlines apply to nested usages

DEADLINE EXAMPLE



```
var deadline = Instant.now().plusMillis(8);

try (ExecutorService executor = Executors.newVirtualThreadExecutor(deadline)) {

    // Submits two value-returning tasks to get a Stream that is lazily populated
    // with completed Future objects as the tasks complete
    Stream<Future<String>> stream = executor.submit(List.of(() -> "foo", () -> "bar'
    stream.filter(Future::isCompletedNormally)
            .map(Future::join)
            .forEach(System.out::println);
}
```

DEBUGGING

Virtual threads are just objects in the heap, there may be millions of them. There is no API support in the debugger API for enumerating all virtual threads.

Virtual threads are not active members of a thread group.

JDWP EventRequest/Set defines a new *PlatformThreadsOnly* filter that can be used when requesting THREAD_START and THREAD_END events.

JDI ThreadReference defines isVirtual() to test if a thread is a virtual thread.

DEBUGGING

Temporarily, VirtualMachine defines supportVirtualThreads() to test if the target VM supports virtual threads.

Temporary JDWP options

- enumeratevthreads=y|n with default as “n”
- notifyvthreads=y|n with default as “y”

DEMO

REFERENCES

- Project Loom Wiki Page https://wiki.openjdk.java.net/display/loom
- Early Access Builds on Java 18 https://jdk.java.net/loom/

EVALUATE THE SESSION

Please help by rating and giving the feedback.

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THANK YOU!