Scoop about scopes

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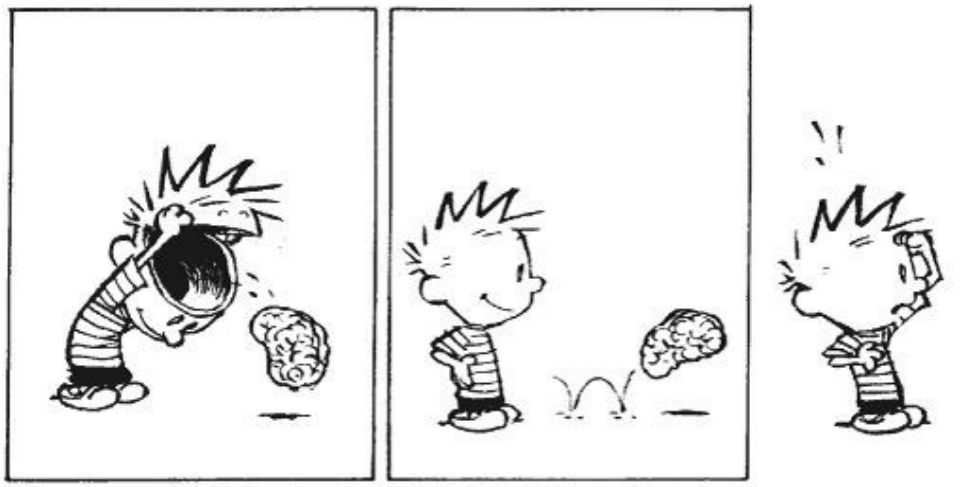
Rémi Forax ?

- Tenured Assistant Prof at Gustave Eiffel University
- Expert for Java spec
  - invokedynamic, lambda, module, text block, enhanced switch, record, sealed class, etc
- OpenSource developer
  - ASM, github.com/forax



Don’t believe what I’m saying !

Get an Episode of Rick & Morty

With a blocking call

```
static Episode getEpisode(int episodeId) throws IOException, InterruptedException {
  try(var httpClient = HttpClient.newHttpClient()) {
      var request = HttpRequest.newBuilder()
          .uri(URI.create("https://rickandmortyapi.com/api/episode/" + episodeId))
          .GET()
          .build();
      var response = httpClient.send(request, HttpResponse.BodyHandlers.ofInputStream());
      var objectMapper = new ObjectMapper();
      return objectMapper.readValue(response.body(), Episode.class);
  }
}
```

Get an Episode of Rick & Morty

With a CompletableFuture

```
static CompletableFuture<Episode> getEpisode(int episodeId) {
    try (var httpClient = HttpClient.newHttpClient()) {
        var request = HttpRequest.newBuilder()
            .uri(URI.create("https://rickandmortyapi.com/api/episode/" + episodeId))
            .GET()
            .build();
        return httpClient.sendAsync(request, HttpResponse.BodyHandlers.ofInputStream())
            .thenCompose(response -> {
                var objectMapper = new ObjectMapper();
                Episode episode;
                try {
                    episode = objectMapper.readValue(response.body(), Episode.class);
                } catch (IOException e) {
                    return CompletableFuture.failedFuture(e);
                }
                return CompletableFuture.completedFuture(episode);
            });
    }
}
```

Async/Await

With an asynchronous call + async/await

```
static async Episode getEpisode(int episodeId) throws IOException, InterruptedException {
  try(var httpClient = HttpClient.newHttpClient()) {
      var request = HttpRequest.newBuilder()
          .uri(URI.create("https://rickandmortyapi.com/api/episode/" + episodeId))
          .GET()
          .build();
      var response = await httpClient.sendAsync(request, HttpResponse.BodyHandlers.ofInputStream());
      var objectMapper = new ObjectMapper();
      return objectMapper.readValue(response.body(), Episode.class);
  }
}
```

made up language: Java + JavaScript

OpenJDK Project Loom

Users write synchronous code, the JDK executes asynchronous calls

Virtual Threads

JDK Threads that can be attached/detached to/from an OS threads

- Preview in Java 19, Final in Java 21

Virtual Threads

```
// platform threads
var pthread = new Thread(() -> {
  System.out.println("platform " + Thread.currentThread());
});
pthread.start();
pthread.join();

// virtual threads
var vthread = Thread.startVirtualThread(() -> {
  System.out.println("virtual " + Thread.currentThread());
});
vthread.join();
```

Get an Episode of Rick & Morty

With an asynchronous call + virtual threads

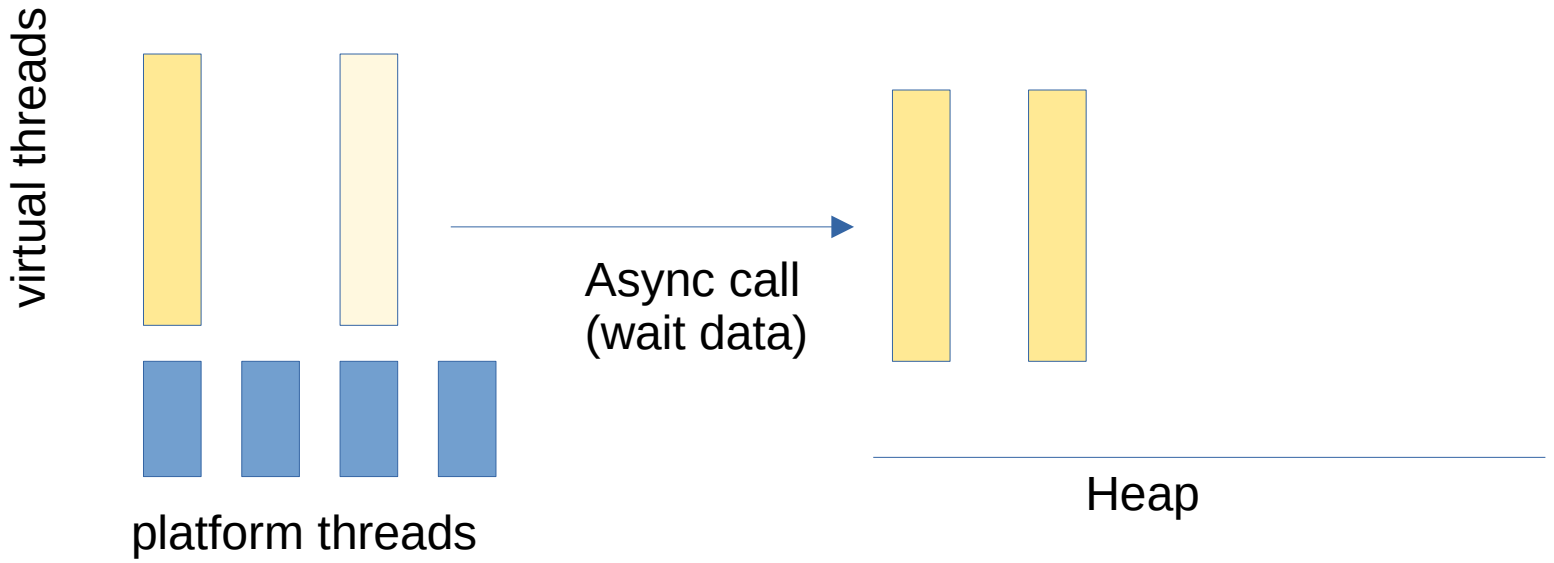
```
static Episode getEpisode(int episodeId) throws IOException, InterruptedException {
  try(var httpClient = HttpClient.newHttpClient()) {
      var request = HttpRequest.newBuilder()
          .uri(URI.create("https://rickandmortyapi.com/api/episode/" + episodeId))
          .GET()
          .build();
      var response = httpClient.send(request, HttpResponse.BodyHandlers.ofInputStream());
      var objectMapper = new ObjectMapper();
      return objectMapper.readValue(response.body(), Episode.class);
  }
}
```

Behind the scene (1/3)

Virtual threads run on top of platform (OS) threads

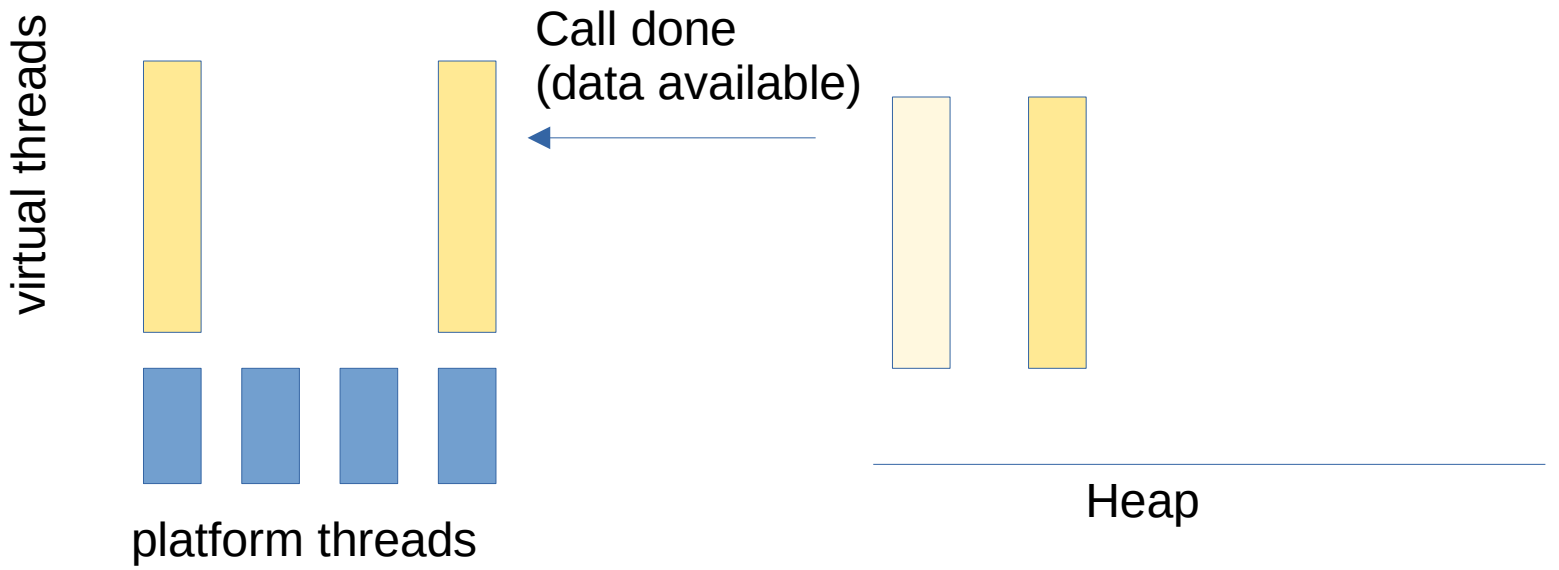
Behind the scene (2/3)

Async call: the virtual thread is copied to the heap



Behind the scene (3/3)

Data are available: the virtual threads is copied back on a stack



How to run several async calls in parallel ?

ExecutorService API ?

```
var executor = Executors.newVirtualThreadPerTaskExecutor();
var future1 = executor.submit(() -> {
    Thread.sleep(10);
    return ...
});
var future2 = executor.submit(() -> {
    Thread.sleep(1_000);
    return ...
});
executor.shutdown();
var result = future1.get() + future2.get();
System.out.println(result);
```

Oooooooops

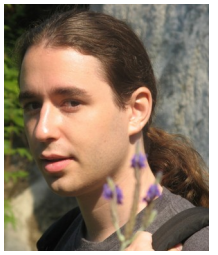
Structured Concurrency

Structured programming for concurrency

- Structured code (goto is harmful)
  - if, while, etc are better than goto

- ExecutorService.submit() is like a goto !

Nathaniel J. Smith



WED 25 APRIL 2018

Notes on structured concurrency, or: Go statement considered harmful

Every concurrency API needs a way to run code concurrently. Here's some examples of what that looks like using different APIs:

```
go myfunc();                                // Golang

pthread_create(&thread_id, NULL, &myfunc);  /* C with POSIX threads */

spawn(modulename, myfuncname, [])           % Erlang

threading.Thread(target=myfunc).start()     # Python with threads

asyncio.create_task(myfunc())               # Python with asyncio
```

There are lots of variations in the notation and terminology, but the semantics are the same: these all arrange for `myfunc` to start running concurrently to the rest of the program, and then return immediately so that the parent can do other things.

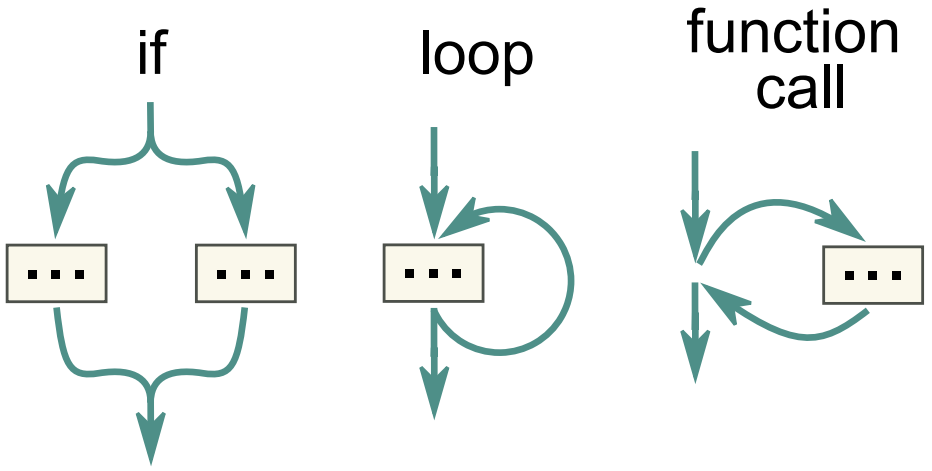
https://vorpus.org/blog/notes-on-structured-concurrency-or-go-statement-considered-harmful/

Structured Concurrency

Structured programming for concurrency

- Structured code (goto is harmful)

  if, while, function calls, etc are better than goto



Structured Concurrency

Is ExecutorService.submit()/Future.get() a goto ?

Change in Java 19

ExecutorService now implements AutoClosable

```
try(var executor = …) {
  var future = executor.submit(() - > { … });
  var future2 = executor.submit(() - > { … });
  ...
} // all threads are dead here
```

Structured Concurrency

Parent/child relationship between a task and its subtasks

- No runaway threads
  - all threads have finished at the end
- No ignored exceptions
  - exceptions are not be swept under the rug

StructuredTaskScope

run several async calls in parallel

(preview feature in Java 21)

StructuredTaskScope

```
try(var sts = new StructuredTaskScope<...>()) {
   …  // starts threads
   sts.join();  // wait for all threads
   …  // collect results
}  // clean threads
```

Example of StructuredTaskScope

```
try(var sts = new StructuredTaskScope<Integer>()) {
  var task = sts.fork(() -> 3);
  var task2 = sts.fork(() -> 42);

  sts.join();

  var result = task.get() + task2.get();
}
```

Big Picture

As a user, it’s two levels of API

- Primary API (STS)
  - **try**(**var** sts = **new** STS<...>()) { ...
  - sts.join()
- Secondary API (Subtask)
  - **Subtask**<...> task = sts.fork(…)
  - task.state(), task.get() or task.exception()

SUCCESS, FAILED, UNAVAILABLE

STS and STS subclasses

StructuredTaskScope offers two subclasses

- STS.ShutdownOnSuccess(), stop when one task succeed
- STS.ShutdownOnFailure(), stop if one task failed

StructuredTaskScope can also be inherited

```
class MySTS extends STS<Integer> {
  // called concurrently by all threads after completion
  public void handleComplete(Task<? extends Integer> task) {
     task.state()  // only SUCCESS or FAILED
     ...
  }
}
```

Demo

ShutdownOnSuccess

The result is available on the STS

```
int value;
try(var sts = new STS.ShutdownOnSuccess<Integer>()) {
  sts.fork(() - > …);
  sts.fork(() - > …);
  value = sts.join()
              .result();  // T or throws ExecutionException
}
```

ShutdownOnFailure

The exception is available on the STS

```
int result;
try(var sts = new STS.ShutdownOnFailure()) {
  var task1 = sts.fork(() - > …);
  var task2 = sts.fork(() - > …)

  sts.join()
       .throwIfFailed();  // may throw ExecutionException

  result = task1.get() + task2.get();
}
```

Timeout

```
try (var scope = new StructuredTaskScope<>()) {
  var task1 = scope.fork(() →...);
  var task2 = scope.fork(() -> ...);

  try {
      scope.joinUntil(Instant.now().plus(Duration.ofMillis(100)));
  } catch (TimeoutException e) {
    ...
  }

  System.out.println(task1.state());  // may be UNAVAILABLE if timeout
  System.out.println(task2.state());  // may be UNAVAILABLE if timeout
}
```

Iteratively improve the API
(for Java 22 ??)

STS API Issues for me

Issues I would like to fix:

- ShutdownOnXXX can be misused if throwIfFailed()/result() are not used
- Exceptions are erased to Throwable and wrapped
- STS.handleComplete(Subtask<...>) is too dangerous !
  - Also SubTask states are different inside/outside of handleComplete()

Demo

STSShutdownOnSuccess

fork() returns void, exceptions are propagated by joinAll()

```
try (var scope =
        new STSShutdownOnSuccess<Integer, RuntimeException>()) {
    scope.fork(() -> ...);
    scope.fork(() ->…);

    var result = scope.joinAll();    // Integer or throws RuntimeException

    System.out.println(result);
}
```

STSShutdownOnFailure

Subtasks are typed by the return values, scope by the exception

```
try (var scope =
        new STSShutdownOnFailure<IOException>()) {
    Subtask<Integer> task1 = scope.fork(...);
    Subtask<Integer> task2 = scope.fork(...);

    scope.joinAll();  // may throw IOException

    System.out.println(task1.get() + task2.get());

}
```

STSAsStream

joinAll() provides a stream of the finished tasks (Result)

```
try (var scope = new STSAsStream<Integer, IOException>()) {
   var task1 = scope.fork(...);
   var task2 = scope.fork(...);

   List<Result<Integer,IOException>> list =
       scope.joinAll(stream -> stream.toList());
   System.out.println(list);

}
```

Result<T,E> acts as an union: Success(T) | Failed(E)

STSAsStream short circuit

If the stream finished, tasks still running are cancelled

```
try (var scope = new STSAsStream<Integer, IOException>()) {
   var task1 = scope.fork(...);
   var task2 = scope.fork(...);

   Optional<Integer> optional =
       scope.joinAll(s -> s.flatMap(Result::keepOnlySuccess).findFirst());

   System.out.println(optional);

}
```

Executive Summary

Summary

Structured concurrency idea is cool

- JEP 453: Structured Concurrency
  - https://openjdk.org/jeps/453
- and in the future (maybe?) https://github.com/forax/loom-fiber/tree/java21