Curs 7

Taskuri

Future-Promise

Executie asincrona

Executori

Apeluri asincrone

- Future
- Promise

Istoric

- Termenul *promise* a fost propus de catre Daniel P. Friedman si David Wise in 1976;
- ~ aceeasi perioada Peter Hibbard l-a denumit *eventual*;
- conceptul *future* a fost introdus in 1977 intr-un articol scris de catre Henry Baker si Carl Hewitt .
- *Future* si *promise* isi au originea in programarea functionala si paradigmele conexe (progr. logica)
- Scop: **decuplarea unei valori (*a future*) de ceea ce o calculeaza**
  – Permite calcul flexibil si paralelizabil
- Folosirea in programarea Paralela si distribuita a aparut ulterior

  mai intai pentru

  – reducerea latentei de comunicatie (*round trips*).

  apoi

  – in programele asincrone.

Promise pipelining

Barbara Liskov and Liuba Shrira in 1988

Mark S. Miller, Dean Tribble and Rob Jellinghaus 1989

```
Conventional RPC
 t3 := ( x.a() ).c( y.b() )
```

Echivalent cu

```
 t1 := x.a();
 t2 := y.b();
 t3 := t1.c(t2); //executie dupa ce t1 si t2 se termina
```

Daca folosim apel *remote* atunci este nevoie de 3 round-trip.
(a,b,c se executa remote)

Folosind futures

```
("Dataflow" with Promises)
t3 := (x <- a()) <- c(y <- b())
Echivalent cu
t1 := x <- a()
t2 := y <- b()
t3 := t1 <- c(t2)
```

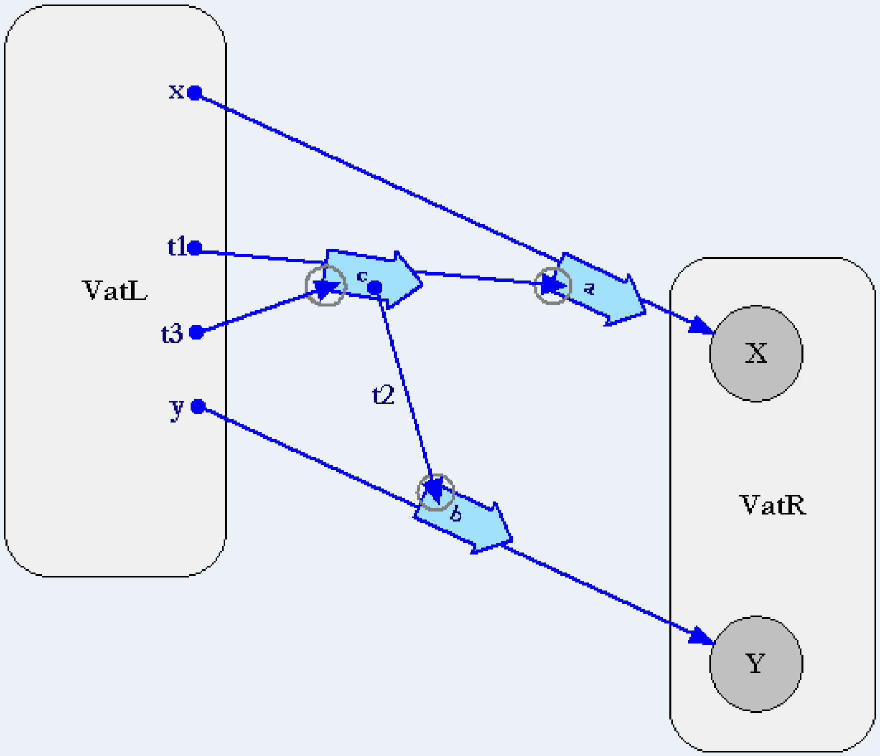
Daca x, y, t1, si t2 sunt localizate pe aceeasi masina remote atunci se poate rezolva in 1 round-trip.
- O cerere trimisa si un raspuns necesar!

Promise Pipelining

From http://www.erights.org/elib/distrib/pipeline.html

The key is that later messages can be sent specifying promises for the results of earlier messages as recipients or arguments, despite the fact that these promises are unresolved at the time these messages are sent.

This allows to stream out all three messages at the same time, possibly in the same packet.



Suppose VatL is a kind of client, making use of a service offered by server VatR.

- a() is delivered to X, which, computes (finds or generates) a local object T1 as a result.
- b() is delivered to Y, which, computes (finds or generates) a local object T2 as a result.
- when c(...) arrives at VatR, t1 is supposed to be already resolved to T1, so c(...) gets delivered to T1, with a t2 argument that's already resolved to the local object T2.

Evaluare

- *call by future*
  - *non-deterministic*: valoarea se va calcula candva intre momentul crearii variabilei *future* si momentul cand aceasta se va folosi
  - *eager evaluation:* imediat ce future a fost creata
  - *lazy evaluation*, doar atunci cand e folosita

  Odata ce valoarea a fost atribuita nu se mai recalculeaza atunci cand se refoloseste.
- *lazy future* : calculul valorii incepe prima oara cand aceasta este ceruta (folosita)
  - e.g. in C++11
    - Politica de apel *std::launch::deferred* ->La apelul *std::async*.

- **Future and Promise**
  - the two sides of an asynchronous operation:
  - **consumer/caller** vs. **producer/implementor**
  - a **caller** of an asynchronous task will get a **Future** as a handle to the computation's result
  - **Future** handles the computation's result
    - e.g. call get()
  - The **implementor** must return a **Future**
    - it is responsible for completing that future as soon as the computation is done.

Blocking vs non-blocking semantic

- Accesare sincrona->
  - De exemplu la transmiterea unui mesaj (se asteapta pana la primirea mesajului)
- Asincron – nu se se blocheaza…(doar se verifica…)
- Accesare sincrona-> posibilitati:
  - Accesul blocheaza threadul curent /procesul pana cand se calculeaza valoarea (eventual timeout).
  - Accesul sincronizat poate produce o eroare (aruncare exceptie)
  - Se poate obtine fie succes daca valoarea este deja calculata sau se transmite eroare daca nu este inca calculata -> poate introduce race conditions.

- in C++11, un thread care are nevoie de valoarea unei *future* se poate bloca pana cand se calculeaza (wait() ori get()). Eventual timeout.
  - Daca future a aparut prin apelul de tip `std::async` atunci un apel `wait` cu blocare poate produce invocare sincrona a functiei care calculeaza rezultatul.

C++11

- future
  - promise
  - async
  - packaged_task

Future

(1) future from packaged_task
(2) future from async()
(3) future from promise

packaged_task

- std::packaged_task object = wraps a callable object

callable object:

- *can be wrapped in a std::function object,*
- *passed to a std::thread as the thread function,*
- *passed to another function that requires a callable object,*
- *invoked directly.*

async

- async
  - Executa o functia **f** asyncron
    - posibil in alt thread si
  - returneaza un obiect std::future care va contine rezultatul

async

- Depinde de implementare daca std::async porneste un nou thread sau daca taskul se va executa sincron atunci cand se cere valoarea pt future.
  - std::launch::deferred - se amana pana cand se apeleaza fie wait() fie get() si se va rula in threadul curent (care poate sa nu fie cel care a apelat async) (lazy evaluation)
  - std::launch::async - se ruleaza in thread separat

Constant	Explanation
std::launch::async	a new thread is launched to execute the task asynchronously
std::launch::deferred	the task is executed on the calling thread the first time its result is requested (lazy evaluation)

std::promise

- Furnizeaza un mecanism de a stoca o valoare sau o exceptie care va fi apoi obtinuta asincron via un obiect std::future care a fost creat prin obiectul promise.
- Actiuni:
  - *make ready*: se stocheaza rezultatul in ‘shared state’.
    - Deblocheaza threadurile care asteapta actualizarea unui obiect future asociat cu ‘shared state’.
  - *release*: se elibereaza referinta la ‘shared state’.
  - *abandon*: shared state = *ready +*
    - exception of type std::future_error with error code std::future_errc::broken_promise

std::promise

promise furnizeaza un obiect future.

- Se furnizeaza si un mecanism de transfer de informatie intre threaduri
  - T1-> wait()
  - T2-> set_value() => future ready.
- d.p.d.v al threadului care asteapta nu e important de unde a aparut informatia.

std::promise specification

- The class template std::promise provides a facility to store a value or an exception that is later acquired asynchronously via a std::future object created by the std::promise object.
- Note that the std::promise object is meant to be used only once.

- Each promise is associated with a shared state, which contains some state information and a result which may be not yet evaluated, evaluated to a value (possibly void) or evaluated to an exception. A promise may do three things with the shared state:

  - make ready: the promise stores the result or the exception in the shared state. Marks the state ready and unblocks any thread waiting on a future associated with the shared state.
  - release: the promise gives up its reference to the shared state. If this was the last such reference, the shared state is destroyed. Unless this was a shared state created by std::async which is not yet ready, this operation does not block.
  - abandon: the promise stores the exception of type std::future_error with error code std::future_errc::broken_promise, makes the shared state ready, and then releases it.

- The promise is the "push" end of the promise-future communication channel: the operation that stores a value in the shared state synchronizes-with (as defined in std::memory_order) the successful return from any function that is waiting on the shared state (such as std::future::get). Concurrent access to the same shared state may conflict otherwise: for example multiple callers of std::shared_future::get must either all be read-only or provide external synchronization.

Exemple

```
//(1) future from a packaged_task
   std::packaged_task<int()> task( [](){ return 7; }      ); // wrap the function

   std::future<int> f1 = task.get_future();  // get a future

   std::thread(std::move(task)).detach(); // launch on a thread

   //(2) future from an async()
   std::future<int> f2 = std::async(std::launch::async, [](){ return 8; });

   // (3) future from a promise
   std::promise<int> p;
   std::future<int> f3 = p.get_future();

   std::thread( [&p]{ p.set_value_at_thread_exit(9); }).detach();

   f1.wait();
   f2.wait();
   f3.wait();
```

std::shared_future

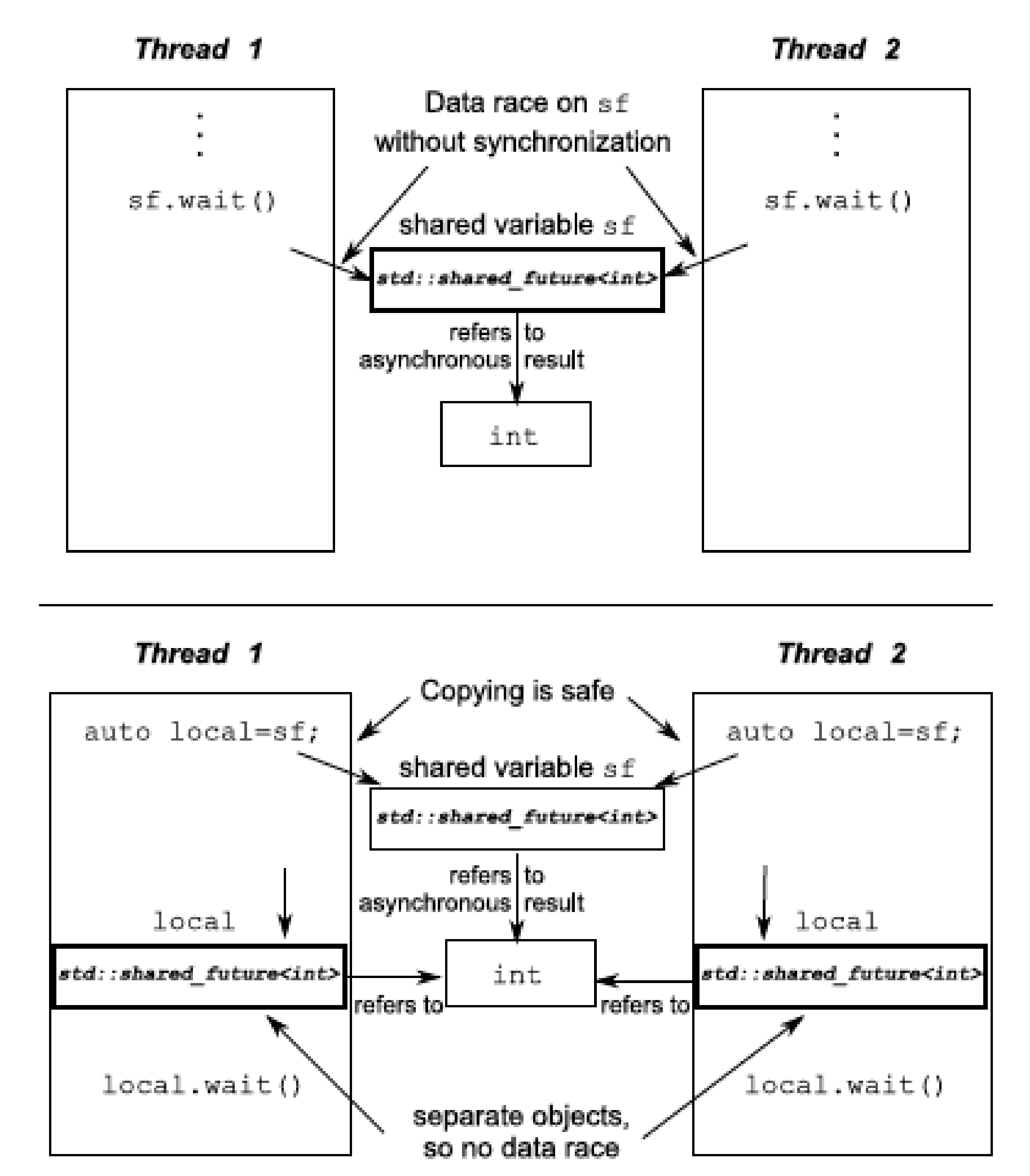
PROBLEMA: daca se acceseaza un obiect std::future din mai multe threaduri fara sincronizare aditionala => ***data race***.

- std::future modeleaza *unique ownership*
  - doar un thread poate sa preia valoarea

- std::shared_future permite accesarea din mai multe threaduri

- std::future este *moveable* (ownership can be transferred between instances)

- std::shared_future este *copyable* (mai multe obiecte pot referi aceeasi stare asociata).



Anthony Williams. C++ Concurrency in Action

std::shared_future, member functions on an individual object are still unsynchronized.

- To avoid data races when accessing a single object from multiple threads, you must protect accesses with a lock.
- The preferred way to use it would be to take a copy of the object instead and have each thread access its own copy.
- Accesses to the shared asynchronous state from multiple threads are safe if each thread accesses that state through its own std::shared_future object.

Java

- task (Runnable vs. Callable)
- Future
- Executor
- CompletableFuture

Task

- Task = activitate independenta
- Nu depinde de :
  - starea,
  - rezultatul, ori
  - ‘side effects’

ale altor taskuri

=> Concurenta /Paralelism

Ref: Java Concurrency in Practice

Exemplul 1

Aplicatii client server-> task = cerere client

```
class SingleThreadWebServer {
public static void main(String[] args) throws IOException {
    ServerSocket socket = new ServerSocket(80);
    while (true) {
        Socket connection = socket.accept();
        handleRequest(connection);
    }
}
....
}
```

Analiza

- procesare cerere =
  - socket I/O (read the request + write the response) -> se poate bloca
  - file I/O or make database requests-> se poate bloca
  - Procesare efectiva

  Single-threaded => ineficient
  - Timp mare de raspuns
  - Utilizare ineficienta CPU

Exemplul 2

```
class ThreadPerTaskWebServer {
        public static void main(String[] args) throws IOException {
                ServerSocket socket = new ServerSocket(80);
                      while (true) {
                        final Socket connection = socket.accept();

                      Runnable task = new Runnable() {
                                      public void run() {
                                        handleRequest(connection);
                                      }
                                };

                        new Thread(task).start();
                        }
        }
...
}
```

Dezavantaje ale nelimitarii numarului de threaduri create

- **Thread lifecycle overhead**
  - Creare threaduri

- **Resource consumption**
  - Threadurile active consuma resursele sistemului (memorie)
  - Multe threaduri inactive bloacheaza spatiu de memorie -> probleme – garbage collector
  - Multe threaduri => probleme cu CPU-> costuri de performanta

- **Stability**
  - exista o limita a nr de threaduri care se pot crea (depinde de platforma)

-> OutOfMemoryError.

Executori

- Task = unitate logica
- Thread -> un mecanism care poate executa taskurile asincron
- Interfata/obiect Executor
  - Mecanism de decuplare a submiterii unui task de executia lui
  - Suport pentru monitorizarea executiei
  - Se bazeaza pe sablonul producator-consumator

```
public interface Executor {
	void execute(Runnable command);
}
```

Exemplu 3

```
class TaskExecutionWebServer {
    private static final int NTHREADS = 50;
    private static final Executor exec= Executors.newFixedThreadPool(NTHREADS);
    public static void main(String[] args) throws IOException {
        ServerSocket socket = new ServerSocket(80);
        while (true) {
            final Socket connection = socket.accept();
            Runnable task = new Runnable() {
                public void run() {
                  handleRequest(connection);
                }
            };
            exec.execute(task);
        }
    }
    ...
}
```

Adaptare – task per thread

```
public class ThreadPerTaskExecutor implements Executor {
	public void execute(Runnable r) {
		new Thread(r).start();
	};
}

\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
public class WithinThreadExecutor implements Executor {
	public void execute(Runnable r) {
		r.run();
	};
}
```
//Executor care executa taskurile direct in threadul apelant (synchronously).

Execution policy

"what, where, when, how" pentru executia taskurilor

= instrument de management al resurselor

- In ce thread se executa un anumit task?
- In ce ordine se aleg taskurile pentru executie (FIFO, LIFO, priority)?
- Cate taskuri se pot executa concurent?
- Cate taskuri se pot adauga in coada de executie?
- Daca sistemul este supraincarcat - *overloaded*, care task se va alege pentru anulare si cum se notifica aplicatia care l-a trimis?
- Ce actiuni trebuie sa fie facute inainte si dupa executia unui task?

Thread pool

- Un executor care gestioneaza un set omogen de threaduri = *worker threads*
- Se foloseste
  - *work queue*
    pentru stocare task-uri
- Worker thread =>
  - cerere task din *work queue*,
  - Executie task
  - Intoarcere in starea de asteptare task.

Variante - Java

- newFixedThreadPool

A fixed-size thread pool creates threads as tasks are submitted, up to the *maximum* pool size, and then attempts to keep the pool size constant (adding new threads if a thread dies due to an unexpected Exception).

- newCachedThreadPool

A cached thread pool has more flexibility to reap idle threads when the current size of the pool exceeds the demand for processing, and to add new threads when demand increases, but places no bounds on the size of the pool.

- newSingleThreadExecutor

A single-threaded executor creates a *single worker thread* to process tasks, replacing it if it dies unexpectedly. Tasks are guaranteed to be processed sequentially according to the order imposed by the task queue (FIFO, LIFO, priority order).

- newScheduledThreadPool

A fixed-size thread pool that supports *delayed and periodic task execution*, similar to Timer.

Runnable vs. Callable

- abstract computational tasks:
  - Runnable
  - Callable
    - Returns a value
- Task
    - Start
    - [eventually] terminates
- Task Lifecycle:
  - created
  - submitted
  - started
  - completed
- Anulare (cancel)
  - Taskurile submise dar nepornite se pot anula
  - Taskurile pornite se pot anula doar daca raspund la intreruperi
  - Taskurile terminate nu sunt influentate de ‘cancel’.

Interfetele Callable si Future

```
public interface Callable<V> {
     V call() throws Exception;
}
public interface Future<V> {
    boolean cancel(boolean mayInterruptIfRunning);
    boolean isCancelled();
    boolean isDone();

    V get() throws InterruptedException, ExecutionException, CancellationException;

    V get(long timeout, TimeUnit unit) throws InterruptedException,ExecutionException,
                                              CancellationException, TimeoutException;
}
```

Java

Future

FutureTask -> A cancellable asynchronous computation.

public class **FutureTask<V>** extends Object implements RunnableFuture<V>

CompletableFuture

apel direct fara executor

```java
public class Test {
	public static class AfisareMesaj implements Callable<String>{
		private String msg;
		public AfisareMesaj(String m){
			msg = m;
		}
		public String call(){
			 String threadName = Thread.currentThread().getName();
			//  System.out.println(msg +"  "+ threadName);
			 return msg + "  "+threadName;
		}
	}
public static void main(String a[]){
	FutureTask<String> fs = new FutureTask<String>(new AfisareMesaj("TEST"));
	fs.run();
	try {
		System.out.println(fs.get());
	} catch (InterruptedException | ExecutionException e2) {
			e2.printStackTrace();
	}
```

Suma numere consecutive – afisare rezultate

```
public class MyRunnable implements Runnable {
    private final long countUntil;

    MyRunnable(long countUntil) {
        this.countUntil = countUntil;
    }

    @Override
    public void run() {
        long sum = 0;
        for (long i = 1; i < countUntil; i++) {
            sum += i;
        }
         //global_variable += sum;
    }
}
```

```
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;

public class Main {
    private static final int NTHREADS = 10;
     //static long global_variable = 0;

    public static void main(String[] args) {
        ExecutorService executor = Executors.newFixedThreadPool(NTHREADS);
        for (int i = 0; i < 500; i++) {
            Runnable task = new MyRunnable(10000000L + i);
            executor.execute(task);
        }
        // This will make the executor accept no new threads
        // and finish all existing threads in the queue
        executor.shutdown();
        // Wait until all threads are finish
        executor.awaitTermination(); !!!!!!!!!!!!!!!
        System.out.println("Finished all threads");
    }
}
```

Recommended termination of Executors

```
void shutdownAndAwaitTermination(ExecutorService pool) {
  pool.shutdown(); // Disable new tasks from being submitted
  try {
    // Wait a while for existing tasks to terminate
    if (!pool.awaitTermination(60, TimeUnit.SECONDS)) {
      pool.shutdownNow(); // Cancel currently executing tasks
      // Wait a while for tasks to respond to being cancelled
      if (!pool.awaitTermination(60, TimeUnit.SECONDS))
          System.err.println("Pool did not terminate");
    }
  } catch (InterruptedException ie) {
    // (Re-)Cancel if current thread also interrupted
    pool.shutdownNow();
    // Preserve interrupt status
    Thread.currentThread().interrupt();
  }
```

Exemplu: Futures & Callable
Suma de numere consecutive – acumulare

```
import java.util.concurrent.Callable;

public class MyCallable implements Callable<Long> {
    @Override
    public Long call() throws Exception {
        long sum = 0;
        for (long i = 0; i <= 10000; i++) {
            sum += i;
        }
        return sum;
    }

}
```

```java
import java.util.ArrayList;
import java.util.List;
import java.util.concurrent.Callable;
import java.util.concurrent.ExecutionException;
import java.util.concurrent.ExecutorService;
import java.util.concurrent.Executors;
import java.util.concurrent.Future;

public class CallableFutures {
    private static final int NTHREADS = 10;
    private static final int MAX = 200;

  public static void main(String[] args) {
    ExecutorService executor =
        Executors.newFixedThreadPool(NTHREDS);
    List<Future<Long>> list =
                new ArrayList<Future<Long>>();
   for (int i = 0; i <MAX; i++) {
     Callable<Long> worker = new MyCallable();
      Future<Long> submit =
                        executor.submit(worker);
      list.add(submit);
  }
```

```java
 long global_sum = 0;
        System.out.println(list.size());
        // now retrieve the result
        for (Future<Long> future : list) {
            try {
                global_sum += future.get();
            } catch (InterruptedException e) {
                e.printStackTrace();
            } catch (ExecutionException e) {
                e.printStackTrace();
            }
        }
        System.out.println(global_sum);
        executor.shutdownNow();
    }
}
```

CompletableFuture (from docs...)

- *A Future that may be explicitly completed (setting its value and status), and may be used as a CompletionStage, supporting dependent functions and actions that trigger upon its completion.*
- *When two or more threads attempt to complete or cancel a CompletableFuture, only one of them succeeds.*
- *CompletableFuture implements interface CompletionStage with the following policies:*
  - *Actions supplied for dependent completions of non-async methods may be performed by the thread that completes the current CompletableFuture, or by any other caller of a completion method.*
  - ***All async methods without an explicit Executor argument are performed using the ForkJoinPool.commonPool()** (unless it does not support a parallelism level of at least two, in which case, a new Thread is created to run each task).*
    - *To simplify monitoring, debugging, and tracking, all generated asynchronous tasks are instances of the marker interface CompletableFuture.AsynchronousCompletionTask.*
  - *All CompletionStage methods are implemented independently of other public methods, so the behavior of one method is not impacted by overrides of others in subclasses.*

runAsync

```
CompletableFuture<Void> future = CompletableFuture.runAsync(
        () -> {
            try {      TimeUnit.SECONDS.sleep(1);    }
             catch (InterruptedException e) {       throw new IllegalStateException(e);    }

            System.out.println("I'll run in a separate thread than the main thread.");
        }
);

future.get();
```

- asynchronous task to be executed doesn't produce any result.

supplyAsync

```
CompletableFuture<String> future = CompletableFuture.supplyAsync(
    new Supplier<String>() {
      @Override
       public String get() {
              try {         TimeUnit.SECONDS.sleep(5);       }
              catch (InterruptedException e) {          throw new IllegalStateException(e);       }

              return "Result of the asynchronous computation";
            }
            }
);
String result = future.get();
```

- *supplyAsync()* is employed when the asynchronous task yields a result

Variants of runAsync() and supplyAsync()

```
static CompletableFuture<Void>  runAsync(Runnable runnable)

static CompletableFuture<Void>  runAsync(Runnable runnable, Executor executor)

static <U> CompletableFuture<U> supplyAsync(Supplier<U> supplier)

static <U> CompletableFuture<U> supplyAsync(Supplier<U> supplier, Executor executor)
```

- ForkJoinPool.commonPool()

thenApply

```
// Create a CompletableFuture
CompletableFuture<String> whatsYourNameFuture = CompletableFuture.supplyAsync(
   () -> {  try {      TimeUnit.SECONDS.sleep(1);   }
            catch (InterruptedException e) {      throw new IllegalStateException(e);   }

            return  "Ana";}
);

// Attach a callback to the Future using thenApply()
CompletableFuture<String> greetingFuture = whatsYourNameFuture.thenApply(
        name -> {   return "Hello " + name;}
);

// Block and get the result of the future.
System.out.println(greetingFuture.get());
```

- .thenApply - takes a Function<T,R> as an argument

.thenApply(.....).thenApply(

```
CompletableFuture<String> welcomeText = CompletableFuture.supplyAsync(
        () -> {
                try {      TimeUnit.SECONDS.sleep(1);    }
                catch (InterruptedException e) {      throw new IllegalStateException(e);    }
                return ”Ana";})
        .thenApply(name -> {    return "Hello " + name;})
        .thenApply(greeting -> {    return greeting + ", Welcome ! ";}
);

System.out.println(welcomeText.get());
```

thenApply() variants

class CompletableFuture<T>

methods:

```
<U> CompletableFuture<U> thenApply(Function<? super T,? extends U> fn)

<U> CompletableFuture<U> thenApplyAsync(Function<? super T,? extends U> fn)

<U> CompletableFuture<U> thenApplyAsync(Function<? super T,? extends U> fn, Executor executor)
```

thenAccept

```
public static String method1(){
        System.out.println("salutare");
        return "salutare";
}
static void method2(String arg){
        System.out.println("greetings " +arg);
}
public static void main( String[] args ) throws InterruptedException{
       System.out.println("Main thread running... thread id: " +
       Thread.currentThread().getId());
       CompletableFuture.supplyAsync(ExempleCompletableFutures::method1).
                                       thenAccept(ExempleCompletableFutures::method2);
       System.out.println("Main thread finished");
}
```

thenApply returns result of curent stage whereas thenAccept does not

thenCompose

```
CompletableFuture<User> getUsersDetail(String userId) {
	return CompletableFuture.supplyAsync(() -> {
		return UserService.getUserDetails(userId);
	});
}
CompletableFuture<Double> getCreditRating(User user) {
	return CompletableFuture.supplyAsync(() -> {
		return CreditRatingService.getCreditRating(user);
	});
}
CompletableFuture<Double> result =
			getUserDetail(userId).thenCompose(user -> getCreditRating(user));
```

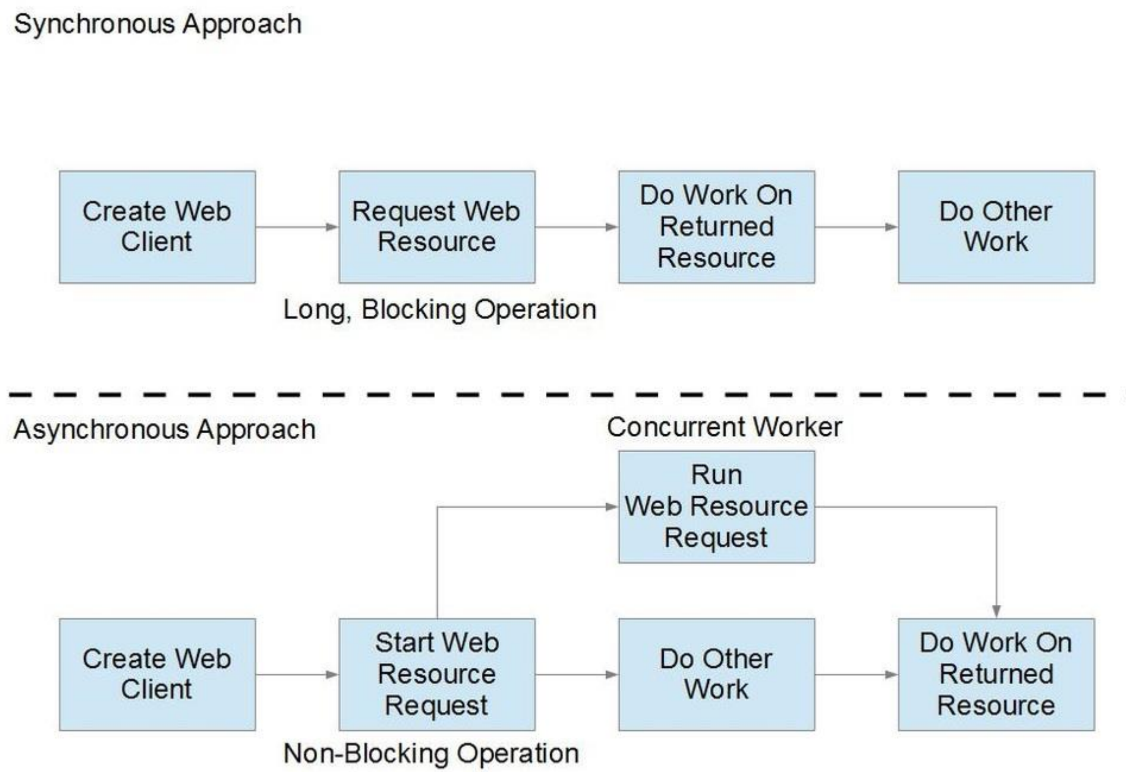
thenCombine

```
System.out.println("Retrieving weight.");
CompletableFuture<Double> weightInKgFuture =
CompletableFuture.supplyAsync(() -> {
   try {
      TimeUnit.SECONDS.sleep(1);
   } catch (InterruptedException e) {
     throw new IllegalStateException(e);
   }
   return 65.0;
});

System.out.println("Retrieving height.");
CompletableFuture<Double> heightInCmFuture =
CompletableFuture.supplyAsync(() -> {
   try {
      TimeUnit.SECONDS.sleep(1);
   } catch (InterruptedException e) {
     throw new IllegalStateException(e);
   }
   return 177.8;
});
```

```
System.out.println("Calculating BMI.");
CompletableFuture<Double> combinedFuture =
weightInKgFuture
        .thenCombine(heightInCmFuture, (weightInKg, heightInCm)
-> {
   Double heightInMeter = heightInCm/100;
   return weightInKg/(heightInMeter*heightInMeter);
});

System.out.println("Your BMI is - " + combinedFuture.get());
```

Variante - metode

Method	**Async method**	**Arguments**	**Returns**
thenRun()	thenRunAsync()	–	–
thenAccept()	thenAcceptAsync()	Result of previous stage	–
thenApply()	thenApplyAsync()	Result of previous stage	Result of current stage
thenCompose()	thenComposeAsync()	Result of previous stage	Future result of current stage
thenCombine()	thenCombineAsync()	Result of two previous stages	Result of current stage
whenComplete()	whenCompleteAsync()	Result or exception from previous stage	–


Synchronous Approach
Create Web Client
Request Web Resource
Do Work On Returned Resource
Do Other Work
Long, Blocking Operation
Asynchronous Approach
Concurrent Worker
Run Web Resource Request
Create Web Client
Start Web Resource Request
Do Other Work
Do Work On Returned Resource
Non-Blocking Operation

Exemplu complex

GitHub - atomix/atomix: A reactive Java framework for building fault-tolerant distributed systems

atomix/PartitionedDistributedCollectionProxy.java at master · atomix/atomix · GitHub