

5. Actor model using the Akka framework

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CISTER – U.Porto, Porto, Portugal

<https://fm-dcc.github.io/cp2526>



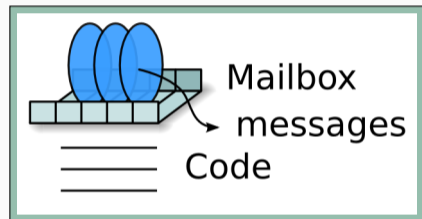
CISTER - Research Centre in
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Overview

Blocks of sequential code running concurrently and sharing memory:

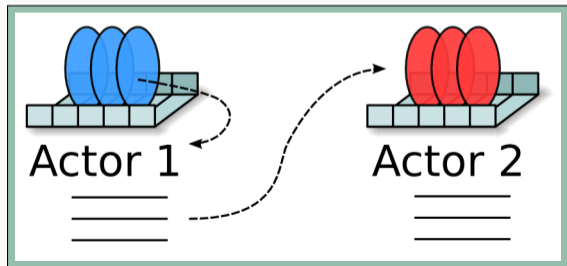
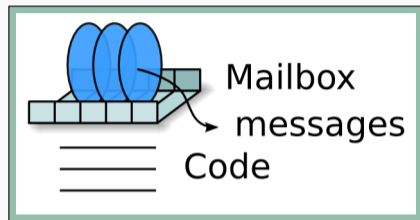
- What is Scala?
- Concurrency in Java and its memory model
- Basic concurrency blocks and libraries
- *Futures and Promises*
- *Data-Parallel Collections*
- *Reactive Programming (Concurrently)*
- *Software Transactional Memory*
- **Actor model**

- **Asynchronous** message exchange between actors
- Introduced in **Erlang** (we use Akka's actor library)



What is the actor model

- **Asynchronous** message exchange between actors
- Introduced in **Erlang** (we use Akka's actor library)
- Active, autonomous, **no shared memory**, no synchronisation



We will use the Akka framework for actors for:

- Declaring **actor classes** and creating **actor instances**
- Modelling **actor state** and complex **actor behaviours**
- Manipulating the **actor hierarchy** and the **actor lifecycle**
- The different message-passing patterns used in **actor communication**
- Error recovery using the built-in **actor supervision** mechanism
- Using **remote actors** to build concurrent and distributed programs

Documentation: <https://doc.akka.io/docs/akka>

Creating actors

Actor system

Hierarchical group of actors with shared configurations, supporting actor creation and logging.

Actor class

Template that describes the states and behaviour of an actor, used to create instances.

Actor instance

Entity that exists at runtime, with a state and capable of sending and receiving messages.

Mailbox

Memory block that is used to buffer messages for a given actor instance.

Actor reference

Object that allows an object to send messages to a specific actor instance.

Dispatcher

Component that decides when actors are allowed to process messages. In Akka every dispatcher is also an execution context.

My first actor (class) in Akka

```
import akka.actor._
import akka.event.Logging

class HelloActor(val hello: String)
  extends Actor {
  val log = Logging(context.system, this)
  def receive = { // Any => Unit (partial)
    case 'hello' =>
      log.info(
        s"Received␣a␣'$hello'...␣'$hello!'")
    case msg      =>
      log.info(
        s"Unexpected␣message␣'$msg'")
      context.stop(self)
  }
}
```

- Each `HelloActor` receives messages
- ... if it receives its `hello`, it logs and `continues`
- ... if it receives something else, it `stops`
- `context` – provides core functions, such as `stop`
- `self` – is the instance's actor reference

```
object HelloActor { // companion
  // two factory methods below
  def props(hello: String) =
    Props(new HelloActor(hello))
  def propsAlt(hello: String) =
    Props(classOf[HelloActor], hello)
  //def propsAlt2 = Props[HelloActor]
}
```

Actor configuration

- actor class
- constructor arguments
- mailbox
- dispatcher

Props

- can receive a block of code, used each time a new actor instance is created;
- can receive a **Class** object and its arguments
- can be sent over the network (should be self-contained)
- avoid creating **Props** in the actor class, and use factory methods instead

```
// in build.sbt:  
libraryDependencies += Seq( ...  
  , "com.typesafe.akka" %% "akka-actor" % "2.8.5"  
  , "com.typesafe.akka" %% "akka-remote" % "2.8.5"  
)
```

```
lazy val ourSystem = akka.actor.ActorSystem("OurExampleSystem")
```

```
object ActorsCreate extends App {  
  val hiActor: ActorRef =  
    ourSystem.actorOf(HelloActor.props("ola"), name = "greeter")  
  hiActor ! "ola"  
  Thread.sleep(1000)  
  hiActor ! "hi"  
  Thread.sleep(1000)  
  ourSystem.terminate()  
}
```

```
import akka.actor._
import akka.event.Logging

object ActorsCreate2 extends App {
  lazy val ourSystem =
    akka.actor.ActorSystem("OurSystem")

  class Hi(val hi: String) extends Actor {
    val log = Logging(context.system, this)
    def receive = {
      case 'hi' =>
        log.info(s"Got a '$hi'... '$hi! ")
      case msg =>
        log.info(s"Unexpected '$msg' ")
        context.stop(self)
    }
  }
}
```

```
val hiActor: ActorRef =
  ourSystem.actorOf(
    Props(new Hi("ola")),
    name = "greeter")

hiActor ! "ola"
// ... Got a 'ola'... ola!
Thread.sleep(1000)
hiActor ! "yo"
// ... Unexpected 'yo'
Thread.sleep(1000)
hiActor ! "privet"
// ... Message (...) was not
// delivered.
Thread.sleep(1000)
ourSystem.terminate()
}
```

```
hiActor ! "ola"
// ... [akka://OurSystem/user/greeter] Got a 'ola'... ola!

Thread.sleep(1000)
hiActor ! "yo"
// ... [akka://OurSystem/user/greeter] Unexpected 'yo'

Thread.sleep(1000)
hiActor ! "privet"
// ... [akka://OurSystem/user/greeter] Message [...] to
      Actor[akka://OurSystem/user/greeter#-726408098] was not delivered.

Thread.sleep(1000)
ourSystem.terminate()
}
```

Unhandled messages?

```
class DeafActor extends Actor {
  val log = Logging(context.system, this)
  def receive = PartialFunction.empty
  // default: ignore and log
  override def unhandled(msg: Any) = msg match {
    case msg: String => log.info(s"I do not hear '$msg'")
    case msg          => super.unhandled(msg)
  }
}
```

```
object ActorsUnhandled extends App {
  val deafActor: ActorRef =
    ourSystem.actorOf(Props[DeafActor], name = "deafy")
  deafActor ! "ola"
  Thread.sleep(1000)
  deafActor ! 1234
  Thread.sleep(1000)
  ourSystem.terminate()
}
```

Modelling actor behaviour

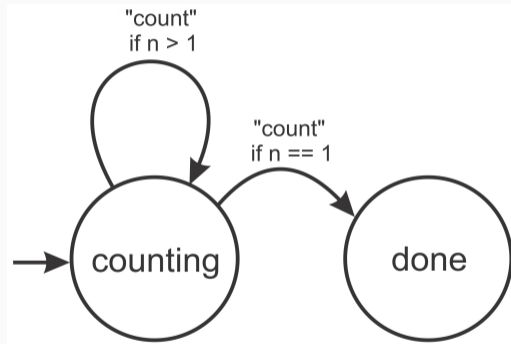
```
class CountdownActor extends Actor{
  var n = 10
      // never do this
  def receive = if (n > 0) {
    case "count" =>
      log(s"n = $n")
      n -= 1
  } else PartialFunction.empty
}
```

Not allowed in Akka:

```
class CountdownActor extends Actor {
  var n = 10
  // never do this
  def receive = if (n > 0) {
    case "count" =>
      log(s"n_=_$n")
      n -= 1
  } else PartialFunction.empty
}
```

Correct in Akka, using become:

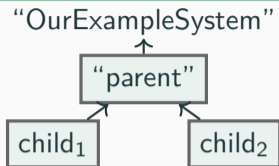
```
class CountdownActor extends Actor {
  val log = Logging(context.system,
    this)
  var n = 10
  def counting: Actor.Receive = {
    case "count" =>
      n -= 1
      log.info(s"n_=_$n")
      if (n == 0) context.become(done)
  }
  def done = PartialFunction.empty
  def receive = counting
}
```



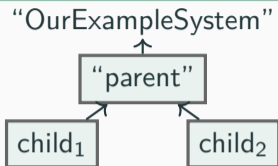
[in *"Learning Concurrent Programming in Scala"*, pg. 278]

```
object ActorsCountdown extends App {  
  val countdown = ourSystem.actorOf(Props[CountdownActor])  
  for (i <- 0 until 20) countdown ! "count"  
  Thread.sleep(1000)  
  ourSystem.terminate()  
}
```

Actor hierarchy and lifecycle



New example with a parent



```

class ChildActor extends Actor {
  val log =
    Logging(context.system, this)
  def receive = {
    case "sayhi" =>
      val parent = context.parent
      log.info(s"my parent $parent
        made me say hi!")
  }
  override def postStop() {
    log.info("child stopped!")
  }
}

```

```

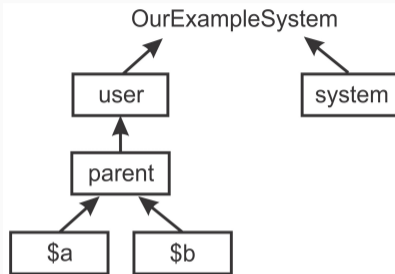
class ParentActor extends Actor {
  val log = Logging(context.system,
    this)
  def receive = {
    case "create" =>
      context.actorOf(Props[ChildActor])
      log.info(s"created a kid;
        children =
          ${context.children}")
    case "sayhi" =>
      log.info("Kids, say hi!")
      for (c <- context.children)
        c ! "sayhi"
    case "stop" =>
      log.info("parent stopping")
      context.stop(self)
  }
}

```

A more complete view of the hierarchy

```
object ActorsHierarchy extends App {
  val parent =
    ourSystem.actorOf(Props[ParentActor],
      "parent")
  parent ! "create"
  parent ! "create"
  Thread.sleep(1000)
  parent ! "sayhi"
  Thread.sleep(1000)
  parent ! "stop"
  Thread.sleep(1000)
  ourSystem.terminate()
}
```

Draw a sequence and a communication diagram (UML)



in "Learning Concurrent Programming in Scala", pg. 284

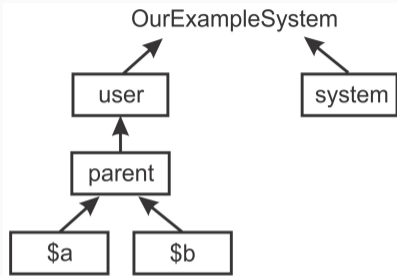
- ActorSystem
- sys.terminate
- sys/ctxt.actorOf
- ctxt.stop
- ctxt.become
- ctxt.children
- ctxt.parent

- **parent** actor stops \Rightarrow its **children** stop
- **user** and **system**:
are **guardian actors** – at the top of the hierarchy, to log, restart actors, etc.
- hierarchy visible when printing an actor ref, e.g., for the first child;
`akka://OurExampleSystem/user/parent/$a`

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akka://OurExampleSystem/user/parent/\$a

- **Next:** `ctxt.actorSelection(path)`



[in "Learning Concurrent Programming in Scala", pg. 284]

- ActorSystem
- sys.terminate
- sys/ctxt.actorOf
- ctxt.stop
- ctxt.become
- ctxt.children
- ctxt.parent

```
class CheckActor extends Actor {
  val log = Logging(context.system, this)
  def receive = {
    case path: String =>
      log.info(s"checking_path_$path")
      context.actorSelection(path) ! Identify(path)
    case ActorIdentity(path, Some(ref)) =>
      log.info(s"found_actor_$ref_at_$path")
    case ActorIdentity(path, None) =>
      log.info(s"could_not_find_an_actor_at_$path")
  }
} // Discovery: actorSelection + Identify + ActorIdentity
```

```
class CheckActor extends Actor {
  val log = Logging(context.system, this)
  def receive = {
    case path: String =>
      log.info(s"checking_path_$path")
      context.actorSelection(path) ! Identify(path)
    case ActorIdentity(path, Some(ref)) =>
      log.info(s"found_actor_$ref_at_$path")
    case ActorIdentity(path, None) =>
      log.info(s"could_not_find_an_actor_at_$path")
  }
} // Discovery: actorSelection + Identify + ActorIdentity
```

```
val checker = ourSystem.actorOf(Props[CheckActor], "checker")

checker ! "../*" // finds the checker and its siblings
checker ! "../../*" // finds user and system guardians
checker ! "/system/*" // finds internal actors
checker ! "/user/checker2" // logs that no actors were found
```

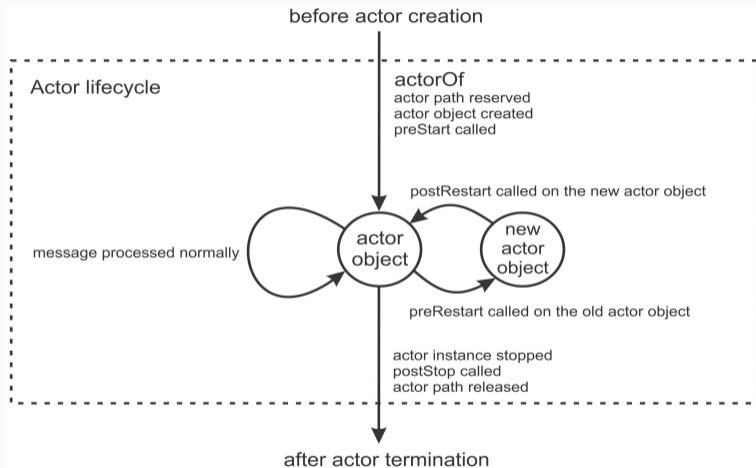
When an actor throws an exception, a new “replacement” actor is created, with the same:

- arguments
- mailbox
- ActorRef

When an actor throws an exception, a new “replacement” actor is created, with the same:

- arguments
- mailbox
- ActorRef
 - hence never leak the actual `this` reference!

- `actorOf` – Creation of an actor reference + instantiation
- `preStart()` – Ran before starting to process messages (**default:** empty)
- `preRestart(t: Throwable, msg: Option[Any])` – Ran after an **exception**:
 - before creating a new replacement actor (same reference)
 - restarting is handled by the parent's **Supervision Strategy** (more later)
 - **default:** stops children + runs `postStop`
- `postRestart(t: Throwable)` – Ran after recreating a restarted actor
 - the new actor is then assigned the previous mailbox
 - **default:** call `preStart()`
- `postStop()` – Ran after an actor terminates (**default:** empty)



[in "Learning Concurrent Programming in Scala", pg.289]

More: <https://doc.akka.io/libraries/akka-core/current/actors.html#classic-actors>

Synchrony vs. Asynchrony

Synchronous (as in CCS)

$$A = x! . y!$$
$$B = x? . y?$$
$$A \mid B \setminus \{x, y\}$$

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$\Rightarrow \tau_x \cdot \tau_y$

Asynchronous (as in Akka)

$x!$ happens before $y!$

$x?$ happens before $y?$

Synchronous (as in CCS)

$A = x! . y!$

$B = x? . y?$

$A \mid B \setminus \{x, y\}$

$\Rightarrow \tau_x . \tau_y$

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$x!$ happens before $y!$

$x?$ happens before $y?$

$x!$ happens before $x?$

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Synchronous (as in CCS)

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$A \mid B \setminus \{x, y\}$

$\Rightarrow \tau_x \cdot \tau_y$

Asynchronous (as in Akka)

$x!$ happens before $y!$

$x?$ happens before $y?$

$x!$ happens before $x?$

$y!$ happens before $y?$

$y!$?? $x?$

Synchronous (as in CCS)

$$A = x! . y!$$
$$B = x? . y?$$
$$A \mid B \setminus \{x, y\}$$
$$\Rightarrow \tau_x \cdot \tau_y$$

Different formalisations for global beh.:

- Message sequence charts
- Event structures
- Automata over interactions
- Choreographies:

$$A \rightarrow B : x \ ; \ A \rightarrow B : y$$

Asynchronous (as in Akka)

$x!$ happens before $y!$

$x?$ happens before $y?$

$x!$ happens before $x?$

$y!$ happens before $y?$

$y!$?? $x?$

No duplication

No messages lost

No messages reordered

No blocking send

Synchrony modelled with Asynchrony?
and vice-versa?

$A \rightarrow B : x;$

$A \rightarrow C : y;$

$C \rightarrow B : z$

B must be ready to receive 'x?' and 'z?' by any order

Error recovery with actors

Main ways to stop an actor:

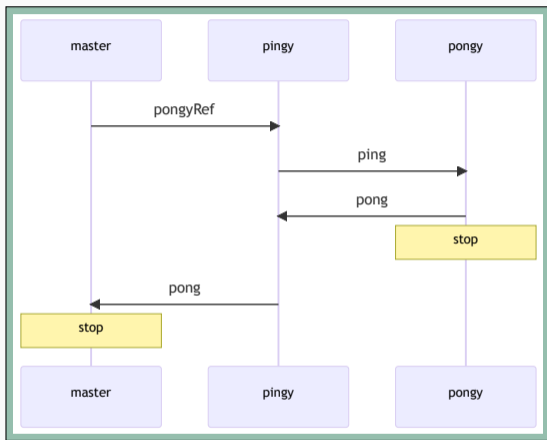
- `context.stop(act)` – stops `act` and its children, once it finishes processing their current message
- `Kill` message – restarts the target actor once it is received
- `PoisonPill` message – stops the target actor after once it is processed

Main ways to stop an actor:

- `context.stop(act)` – stops act and its children, once it finishes processing their current message
- Kill message – restarts the target actor once it is received
- PoisonPill message – stops the target actor after once it is processed

Stopping in more complex scenarios:

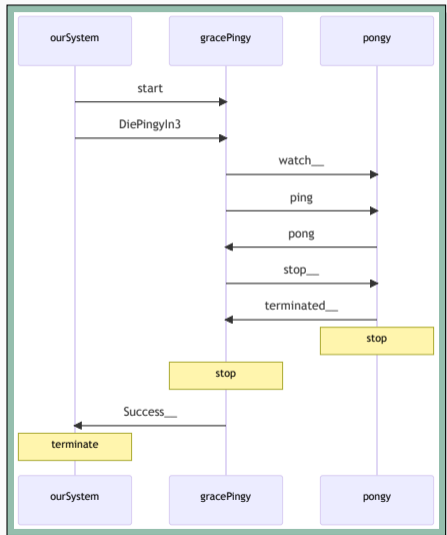
- Using Akka's DeathWatch (next slide)



- Example used in the book to illustrate the ask-reply pattern
- (in pingy: `val reply = pongy ? "ping"`)
- We will adapt it for a graceful shutdown

```
class GracefulPingy extends Actor {
  val log = Logging(context.system, this)
  val pongy =
    context.actorOf(Props[Pongy], "pongy")
  context.watch(pongy)
  def receive = {
    case "start" => pongy ! "ping"
    case "pong"  => log.info("Got a pong")
    case "Die, Pingy!" =>
      context.stop(pongy)
    case Terminated('pongy') =>
      context.stop(self)
  }
}
```

```
class Pongy extends Actor {
  val log =
    Logging(context.system, this)
  def receive = {
    case "ping" =>
      log.info("Got a ping -- ponging back!")
      sender ! "pong"
  }
  override def postStop() =
    log.info("pongy going down")
}
```



Mechanism 1 (pingy ↔ pongy)

- `context.watch(pongy)` – the DeathWatch
- wait for `Terminated` message

Mechanism 2 (ourSystem ↔ pingy)

- ask to "Die"
- check if it terminated – using Futures

```
import akka.pattern.gracefulStop

object CommunicatingGracefulStop extends App {
  val gracePingy = ourSystem.actorOf(Props[GracefulPingy], "gracePingy")
  gracePingy ! "start"

  val stopped = gracefulStop(gracePingy, 3.seconds, "Die, Pingy!")
  stopped onComplete { // stopped is a Future (not covered)
    case Success(x) =>
      log("graceful_shutdown_successful")
      ourSystem.terminate()
    case Failure(t) =>
      log("grace_not_stopped!")
      ourSystem.terminate()
  }
}
```

```
class Naughty extends Actor {
  val log = Logging(context.system, this)
  def receive = {
    case s: String => log.info(s)
    case msg => throw new
      RuntimeException
  }
  override def postRestart(t: Throwable) =
    log.info("naughty restarted")
}
```

```
import SupervisorStrategy._
class Supervisor extends Actor {
  context.actorOf(Props[Naughty],
    "naughty")
  def receive = PartialFunction.empty
  override val supervisorStrategy =
    OneForOneStrategy() {
      case ake: ActorKilledException
        => Restart
      case _ => Escalate
    }
}
```

```
ourSystem.actorOf(Props[Supervisor], "super")
val children = ourSystem.actorSelection("/user/super/*")
children ! "hello" // succeeds
children ! Kill // stops naughty, but super restarts it
children ! "sorry about that" // succeeds
children ! "kaboom".toList // naughty and super throw exception
```

Remote actors over TCP

Compilation with remote actors

`build.sbt`

needs to import
akka-remote:

```
libraryDependencies += Seq(  
  ...  
  , "com.typesafe.akka" %% "akka-actor" % "2.8.5" // or older  
  , "com.typesafe.akka" %% "akka-remote" % "2.8.5"  
)
```

Network config-
ured with Netty
library

```
import com.typesafe.config._  
def remotingConfig(port: Int) = ConfigFactory.parseString(s"""  
  akka {  
    actor.provider = "akka.remote.RemoteActorRefProvider"  
    remote {  
      enabled-transport = ["akka.remote.netty.tcp"]  
      netty.tcp {  
        hostname = "127.0.0.1"  
        port = $port }  
      }  
    }  
  }""")  
def remotingSystem(name: String, port: Int): ActorSystem =  
  ActorSystem(name, remotingConfig(port))
```

```
object RemotingPongySystem extends App {  
  val system =  
    remotingSystem("PongyDimension",  
      24321)  
  val pongy = system.actorOf(Props[Pongy],  
    "pongy")  
  Thread.sleep(15000)  
  system.terminate()  
}
```

```
object RemotingPingySystem extends App {  
  val system =  
    remotingSystem("PingyDimension",  
      24567)  
  val runner = system.actorOf(Props[Runner],  
    "runner")  
  runner ! "start"  
  Thread.sleep(5000)  
  system.terminate()  
}
```

```
class Runner extends Actor {  
  val log = Logging(context.system, this)  
  val pingy = context.actorOf(Props[Pingy], "pingy")  
  def receive = {  
    case "start" =>  
      val pongySys =  
        "akka.tcp://PongyDimension@127.0.0.1:24321"  
      val pongyPath = "/user/pongy"  
      val url = pongySys + pongyPath  
      val selection = context.actorSelection(url)  
      selection ! Identify(0)  
      case ActorIdentity(0, Some(ref)) =>  
        pingy ! ref  
      case ActorIdentity(0, None) =>  
        log.info("Something's wrong - ain't no pongy  
          anywhere!")  
        context.stop(self)  
      case "pong" =>  
        log.info("got a pong from another dimension.")  
        context.stop(self)  
  }  
}
```

- Start the `RemotingPongySystem`
- Start the `RemotingPingySystem` within 15 sec.
- Use different SBT instances
- Runner in `PingyDimension` should get a “pong” soon

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Deployment logic vs. Application logic

- Deployment log.: setting up network communication
- Application log.: interactions between agents
- These should be kept in separate
- In our example, `Runner` handles deployment logic

Steps for handling remote actors

- **Declaring** each actor system with appropriate remoting configuration
- **Starting** each actor system in separate processes or on separate machines
- **Obtain actor references** by using actor path selection
- **Transparently send messages** by using these actor references

- Declare **actor classes** and create **actor instances**
- Model **actor state** and complex **actor behaviours**
- Manipulate the **actor hierarchy** and the **actor lifecycle**
- Use some message-passing patterns used in **actor communication**
- Use error recovery with the built-in **actor supervision** mechanism
- Use **remote actors** to build concurrent and distributed programs

Documentation: <https://doc.akka.io/docs/akka>

