



Introduction: Why Actors?

Principles of Functional Programming

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Where Actors came from

A selection of events in the history of Actors:

Carl Hewitt et al, 1973: Actors invented for research on artificial intelligence

Gul Agha, 1986: Actor languages and communication patterns

Ericsson, 1995: first commercial use in Erlang/OTP for telecommunications platform

Philipp Haller, 2006: implementation in Scala standard library

Jonas Bonér, 2009: creation of Akka

Threads

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- ▶ multiple execution cores within one chip, sharing memory
- ▶ virtual cores sharing a single physical execution core

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Programs running on the computer must feed these cores:

- ▶ running multiple programs in parallel (multi-tasking)
- ▶ running parts of the same program in parallel (multi-threading)

Example: Bank Account

```
class BankAccount {  
  
    private var balance = 0  
  
    def deposit(amount: Int): Unit =  
        if (amount > 0) balance = balance + amount  
  
    def withdraw(amount: Int): Int =  
        if (0 < amount && amount <= balance) {  
            balance = balance - amount  
            balance  
        } else throw new Error("insufficient funds")  
}
```

Example: Bank Account

```
def withdraw(amount: Int): Int = {  
  val b = balance  
  if (0 < amount && amount <= b) {  
    val newBalance = b - amount  
    balance = newBalance  
    newBalance  
  } else {  
    throw new Error("insufficient funds")  
  }  
}
```

Executing this twice in parallel can violate the invariant and lose updates.

Synchronization

Multiple threads stepping on each others' toes:

- ▶ demarcate regions of code with “don't disturb” semantics
- ▶ make sure that all access to shared state is protected

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Primary tools: lock, mutex, semaphore

In Scala every object has a lock: `obj.synchronized { ... }`

Bank Account with Synchronization

```
class BankAccount {  
  
    private var balance = 0  
  
    def deposit(amount: Int): Unit = this.synchronized {  
        if (amount > 0) balance = balance + amount  
    }  
  
    def withdraw(amount: Int): Int = this.synchronized {  
        if (0 < amount && amount <= balance) {  
            balance = balance - amount  
            balance  
        } else throw new Error("insufficient funds")  
    }  
}
```

Composition of Synchronized Objects

```
def transfer(from: BankAccount, to: BankAccount, amount: Int): Unit = {  
  from.synchronized {  
    to.synchronized {  
      from.withdraw(amount)  
      to.deposit(amount)  
    }  
  }  
}
```

Composition of Synchronized Objects

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def transfer(from: BankAccount, to: BankAccount, amount: Int): Unit = {  
  from.synchronized {  
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    }  
  }  
}
```

Introduces Dead-Lock:

- ▶ transfer(accountA, accountB, x) in one thread
- ▶ transfer(accountB, accountA, y) in another thread
- ▶ one lock taken by each, nobody can progress

We want Non-Blocking Objects

- ▶ blocking synchronization introduces dead-locks
- ▶ blocking is bad for CPU utilization
- ▶ synchronous communication couples sender and receiver