Concurrency, Parallelism and Distribution

Concurrency Module

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Introduction

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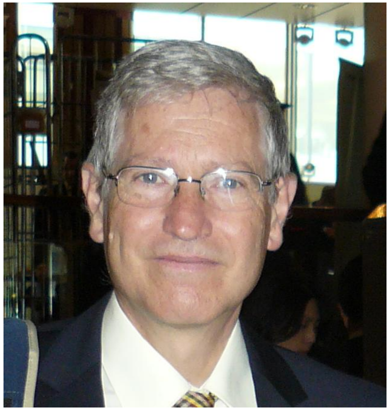


Figure: Joaquim Gabarro

Jorge Castro

Concurrency

Purpose: Concurrency Foundations, mainly through examples.

Concurrency is about interacting programs (or processes).

- Modelling concurrency: LTS (Labeled Transition Systems)

There are two main paradigms:

- Shared Memory: Java. It is object oriented and imperative. Class Thread good for big data structures
- Message Passing: Erlang. It is functional. Each process has a mailbox

good for short messages

Paradigms

In concurrent programs, process interact between the.

- Shared Memory: Process interact accessing shared objects. Intuitively process interact reading and writing to common variables (shared variables). Different processes can access the same memory position. There is no other form of interaction.
- Message Passing: Process interact sending (and receiving) messages. There are no shared variables between the processes. Like in your email, any process has a MailBox.

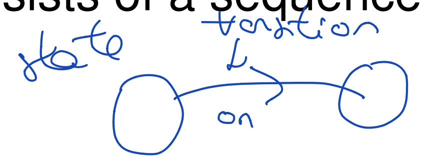
Basic material

- Models
  Jeff Magee and Jeff Cramer
  Concurrency, State Models & Java Programs
  John Wiley & and Sons, 2006.
- Java
  Part of the slides are strongly based in:
  `https://docs.oracle.com/javase/tutorial/`
- Erlang
  Joe Armstrong
  Programming Erlang, Software for a Concurrent World
  Pragmatic Bookshelf, 2007 (first edition).

Shared memory

Modelling Processes

- A process is the execution of a sequential program.
- As a process executes, it transforms its states by executing statements.
- Each statement consists of a sequence of one or more atomic actions.



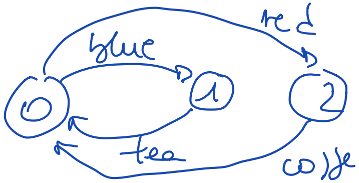
turn on and off lights

You have to download from `http://www.doc.ic.ac.uk/~jnm/book/` and install the Labelled Transition System Analyzer, LTS

action to go

DRINKS = (red → coffe → DRINK | blue → tea → DRINK)

action to return

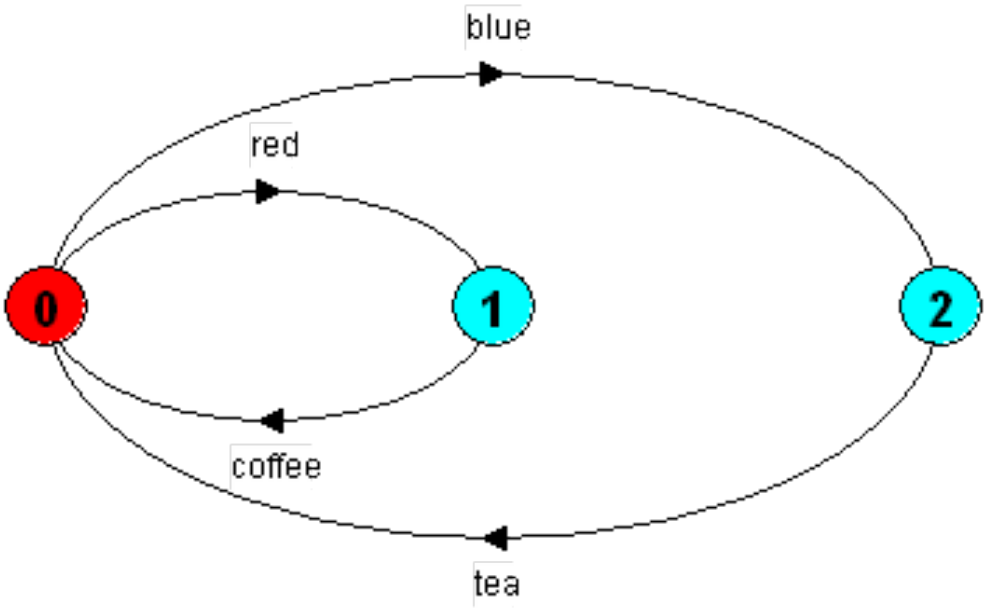


FSP

- We introduce a simple algebraic notation called FSP (for Finite State Process)
- Every FSP description has a corresponding Labelled Transition System.

Example: Drinking machine

```
DRINKS = (red->coffee->DRINKS
          |blue->tea->DRINKS
          ).
```



Example: Drinking machine, traces

A process my have many possible traces

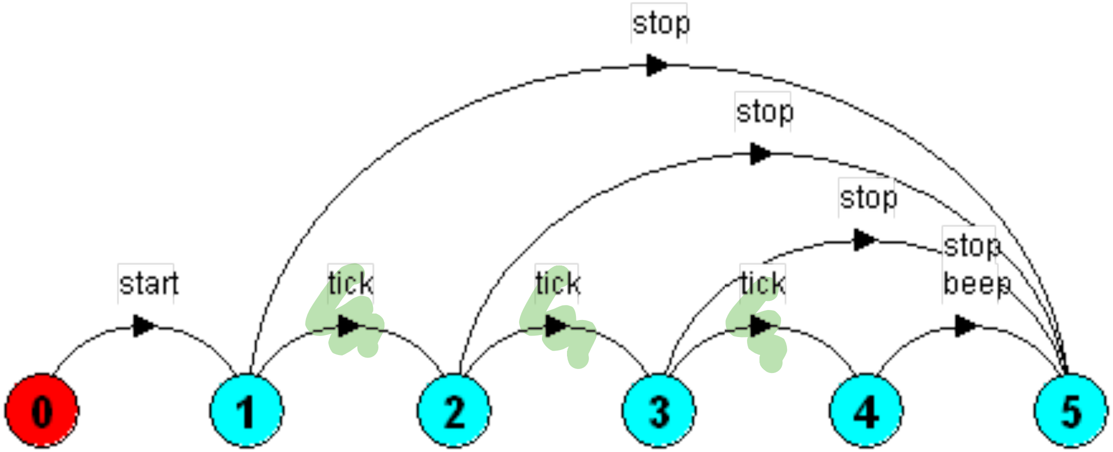
```
red->coffee-> blue->tea-> blue->tea->...
```

```
blue->tea-> red->coffee-> blue->tea->...
```

Look at the *Animator* part of the LST.

Example: Countdown Timer

A countdown timer which beeps after N ticks, or can be stopped.



```
COUNTDOWN (N=3) = (start->COUNTDOWN[N]),
COUNTDOWN[i:0..N] =
          (when(i>0) tick->COUNTDOWN[i-1]
           |when(i==0)beep->STOP
           |stop->STOP).
```

3 ticks

Java: Classes and Objects

A class is a blueprint or prototype from which objects are created.

- A class has atributes (usualy private) and methods (usually public).
- A class has at least a constructor. A constructor has the name of the class.
- The `toString` methods returns a string. Usually prints an object of the class.

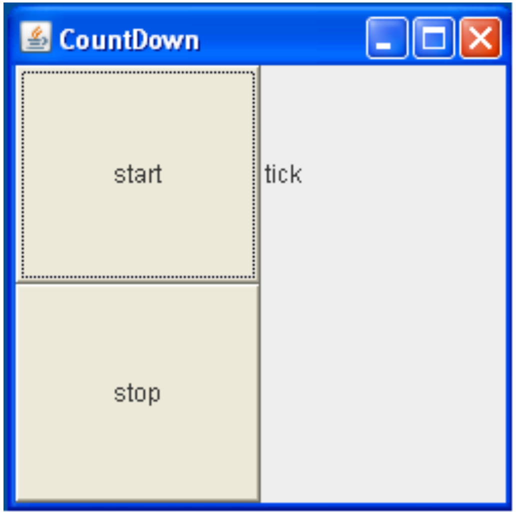
Concurrency: Threads

- A Thread class manages a single sequential thread of control.
- Threads may be created and deleted dynamically.
- An application that creates an instance of Thread must provide the code that will run in that thread.

`http://docs.oracle.com/javase/tutorial/essential/concurrency/runthread.html`

LTS to Java: CountDown

Actions become methods (more or less)



There are two Buttons to start and stop the process. Action tick and beep are displayed as a Label.

Modelling Concurrency

- How should we model process execution speed?
  - Arbitrary speed.
    We abstract away time.
- How do we model concurrency?
  - Arbitrary relative order of actions from different processes.
    Interleaving but preservation of each process order.
- What is the result?
  - Provides a general model independent of scheduling.
    Asynchronous model of execution.

Example: Parallel composition; Action interleaving

(*P*||*Q*) represents the concurrent execution of *P* and *Q*. The operator || is the parallel composition operator.

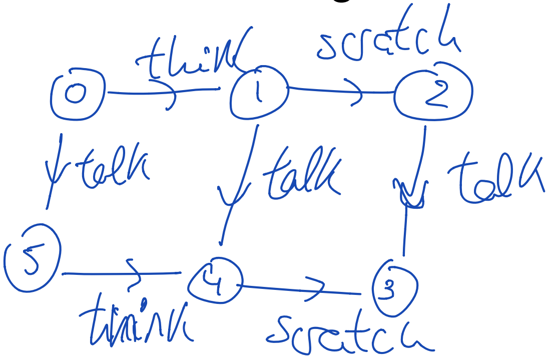
process

```
ITCH = (scratch->STOP).
CONVERSE = (think->talk->STOP).
||CONVERSE_ITCH = (ITCH || CONVERSE).
```

both processes at the same time, or concurrent

Possible traces as a result of action interleaving.

```
think->talk->scratch
think->scratch->talk
scratch->think->talk
```



Message Passing

Reasons why you should learn Erlang

- You want to write programs that run faster when you run them on a multicore computer.
- You want to write fault-tolerant applications that can be modified without taking them out of service.
- You've heard about functional programming and you're wondering whether the techniques really work.
- You don't want to wear your fingers out by typing lots of lines of code.

Variables

All variable names must start with an uppercase letter.

```
1> X = 123456789.
123456789
2> X.
123456789
3> X*X*X*X.
232305722798259244150093798251441
```

Erlang variables can only be bound —to values— once.

Pattern mathching

```
1> Rectangle = {rectangle, 10, 5}.
{rectangle, 10, 5}.
2> Circle = {circle, 2.4}.
{circle,2.40000}
3> {rectangle, Width, Ht} = Rectangle.
{rectangle,10,5}
4> Width.
10
5> Ht.
5
6> {circle, R} = Circle.
{circle,2.40000}
7> R.
2.40000
```

The Concurrency Primitives

you can pas a function as a parameter

function

- Creation of a process: Pid = spawn(Fun)
- Sending a Message: Pid ! Message
- Receiving a message: receive ... end

area as process: area_server0.erl

Download area_server0.erl

```
-module(area_server0).
-export([loop/0]).

loop() ->
  receive
    {rectangle, Width, Ht} ->
      io:format("Area of rectangle is ~p~n", [Width * Ht]),
      loop();
    {circle, R} ->
      io:format("Area of circle is ~p~n", [3.14159 * R * R]),
      loop();
    Other ->
      io:format("I don't know the area of a ~p is ~n",[Other]),
      loop()
  end.
```

→ NO hi ha while a llenguatges funcionals
fes loops amb recursivitat

Evaluating loop/0 in the shell

```
1> Pid = spawn(fun area_server0:loop/0).
<0.36.0>
2> Pid ! {rectangle, 6, 10}.
Area of rectangle is 60
{rectangle,6,10}
3> Pid ! {circle, 23}.
Area of circle is 1661.90
{circle,23}
4> Pid ! {triangle,2,4,5}.
I don’t know the area of a {triangle,2,4,5} is
{triangle,2,4,5}
```

Course organization

Prerequisites

Some basic knowledge on:

- Object oriented programming: classes and objects.
- Finite state machines.
- Recursive programming.

Question: If I do not have some of the prerequisites could I take this course?
Answer: Yes, but you will need to work more. It will be a way to know something on those topics!

Any case we are there to help you!

Scheduling: Theory

Five lectures

- Shared Memory:
  - Models and Problems: Modelling concurrency: FSP and LTS. Interference, lack of coordination and deadlock.
  - Problems and Solutions: Monitors. Wait and notify. Partial solution to deadlock.
  - Correctness: Lamport approach: safety and progress.
- Message Passing:
  - Concurrency on Erlang: Spawning processes. Remote procedure call. Servers.
  - Parallelism and Dynamic Coding: Parallel quicksort. Dynamic code updating.

Scheduler: Lab

- Shared Memory:
  - LTS, LTS Analyser and FSP
  - Models and Java Programs
  - Safety and Progress
- Message Passing:
  - Basics on Erlang
  - Example of Process Interaction Architecture

Do not forget

If any problem or comment or..., do not wait, send and email!

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THANKS!