Starting with Erlang
Sequential Programming in Erlang (Overview)

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Erlang
A Few of History

40+ Years

1981 — the Ericsson CS Lab has been founded.

1981–1986
- a lot of work to decide which paradigm would be better to use in the telecommunication domain;
- conclusions: doesn't exist the perfect paradigm but several characteristics should be mixed.

1987 Erlang is born
- the name is after the Danish mathematician Agner Krarup Erlang but could also mean Ericsson language.

1987–1991
- the JAM ("Joe's Abstract Machine") virtual machine (inspired by the Prolog WAM) has been implemented (in C);
- in 1998 it has been replaced by BEAM ("Bogdan/Björn's Erlang Abstract Machine").

1996 — Open Telecom Platform (OTP) has been released.

1998
- Ericsson stops to develop Erlang but not to use it
- Erlang becomes open source
  - since 2006 the BEAM supports multi-core processors.

Erlang
Overview

Erlang is concurrency oriented, i.e., the process is the basic of every computation.

Erlang adopts the actor's model for concurrency with
- asynchronous message exchange;
- non shared memory

Erlang is a dynamically typed functional language.

Erlang supports distribution, fault tolerance and hot-swapping (dynamic SW updating).

My First Erlang Program
Again a Factorial!!!

```
-module(fact).
-export([fact/1]).
fact(0) -> 1;
fact(N) -> N*fact(N-1).
```

The program must be run through the BEAM shell

```
[12:56]cazzola@mangog:~/lp/erlang>erl
Erlang/OTP 24 [erts-12.3.2.6] [source] [64-bit] [smp:16:16] [async-threads:1] [jit]

Eshell V12.3.2.6  (abort with ^G)
1> c(fact).
{ok,fact}
2> fact:fact(7).
5040
3> fact:fact(100).
933262154439441526816992388562667004907159682643816214685929638952175999932299156089414639761565182862536979208272237582511852109168640000000000000000000000
```

Alternatively it could be run as a script via escript or through native compilation via HiPE.

Sequential Erlang Overview
Numbers and Atoms


```
1> 10.
10
2> 16#FF.
255
3> $A.
65
4> -12.35e-2.
-0.1235
```

- b#val represents the number «val» in base «b»;
- $char is used for ascii values.

```
1> cazzola@di.unimi.it.
'cazzola@di.unimi.it'
2> 'Walter Cazzola'.
'Walter Cazzola'
3> 'Walter^M
3> Cazzola'.
'Walter\nCazzola'
```

- atoms start with lowercase letter but can contain any character;
- if quoted they can start by uppercase letters.

Sequential Erlang Overview
Tuples and Lists


```
1> {123, "walter", cazzola}.
{123, "walter", cazzola}
2> {}.
{}
3> {abc, {'Walter', 'Cazzola'}, 3.14}.
{abc, {'Walter', 'Cazzola'}, 3.14}
4>  {{1, 2}, 3}=={1, {2, 3}}.
false
```

- used to store a fixed number of items;
- tuples of any size, type and complexity are allowed.

```
1> [].
[]
2> [1|[]].
[1]
3> [1|[2]].
[1, 2]
4> [{1,2}, ok, []].
[{1, 2}, ok, []]
5> length([{1, 2}, ok, []]).
3
6> [{1, 2}, ok, []] == [{1, 2}, ok, []].
true
7> A=[$W, $a, $l, $t, $e, $r], B=[$C, $a, $z, $z, $o, $l, $a].
"Cazzola"
8> A++" "++B.
"Walter Cazzola"
9> A--B.
"Wter"
```

- used to store a variable number of items;
- lists are dynamically sized.

Sequential Erlang Overview
Assignments & Pattern Matching


```
1> A = 1.
1
2> A = 2.
** exception error: no match of right hand side value 2
```

- are just name bindings to values and cannot be modified;
- start with an uppercase letter and _ is an anonymous variable.
- the bindings are created via pattern matching.

```
3> [B|L]=[a,b,c].
[a, b, c]
4> {A,B,L}.
{1, a, [b, c]}
5> {X, X} = {B, B}.
{a, a}
6> {Y, Y} = {X, b}.
** exception error: no match of right hand side value {a, b}
7> 1=A.
1
8> 1=Z.
* 1: variable 'Z' is unbound
9> {A1, _, [B1|_], {B1}} = {abc, 23, [22,x], {22}}.
{abc, 23, [22, x], {22}}
10> A1.
abc
11> B1.
22
```

Sequential Erlang Overview
Functions & Modules


```
name(pattern11, pattern12, ..., pattern1n) [when guard1] -> body1 ;
name(pattern21, pattern22, ..., pattern2n) [when guard2] -> body2 ;
                                    ...
name(patternk1, patternk2, ..., patternkn) [when guardk] -> bodyk .
```

- clauses are scanned sequentially until a match is found;
- when a match is found all the variables in the head become bound;

```
-module(ex_module).
-export([double/1]).

double(X) -> double(X, 2).
double(X, N) -> X * N.
```

- double/1 can be called from outside the module, whereas double/2 is local to the module;
- double/1 means the function double with one argument (note that double/1 and double/2 are two different functions).

Sequential Erlang Overview
Functions: Guard Sequences

Each clause in function definition can be guarded by a guard sequence.

- a guard is a sequence $G_1, G_2, \ldots, G_n$ of guard expressions;
- a guard expression is a subset of Erlang expressions guaranteed to be free of side-effects;
- a guard sequence is true when all the guard expressions evaluate to true

Valid guard expression are:

- the atom true and other constants;
- calls to some built-in functions (BIFs);
- arithmetic and boolean expressions; and
- short-circuit expressions (**andalso**/**orelse**).

Permitted BIFs are:

is_atom/1	is_binary/1	is_bitstring/1	is_float/1	is_function/2
is_function/1	is_integer/1	is_list/1	is_number/1	is_pid/1
is_port/1	is_record/2	is_record/3	is_reference/1	is_tuple/1
abs/1	bit_size/1	byte_size/1	element/2	float/1
hd/1	length/1	node/0	node/1	round/1
self/1	size/1	tl/1	trunc/1	tuple_size/1

Sequential Erlang Overview
Map, Filter & Reduce


```
-module(mfr).
-export([map/2,filter/2,reduce/2]).

map(_, []) -> [];
map(F, [H|TL]) -> [F(H)|map(F,TL)].

filter(_, []) -> [];
filter(P, [H|TL]) -> filter(P(H), P, H, TL).

filter(true, P, H, L) -> [H|filter(P, L)];
filter(false, P, _, L) -> filter(P, L).

reduce(F, [H|TL]) -> reduce(F, H, TL).

reduce(_, Q, []) -> Q;
reduce(F, Q, [H|TL]) -> reduce(F, F(Q,H), TL).
```

```
1> mfr:map(fun(X) -> X*X end, [1,2,3,4,5,6,7]).
[1, 4, 9, 16, 25, 36, 49]
2> mfr:filter(fun(X) -> (X rem 2)==0 end, [1,2,3,4,5,6,7]).
[2, 4, 6]
3> mfr:reduce(fun(X,Y) -> X+Y end, [1,2,3,4,5,6,7]).
28
```

They are available in the module lists.

Sequential Erlang Overview
List Comprehensions


```
[X||Qualifier1, ..., Qualifiern]
```

X is an expression, each qualifier is a generator or a filter

- generators are in the form Pattern <- ListExpr where ListExpr evaluates to a list;
- filters are either predicates or boolean expressions.

```
-module(sort).
-export([qsort/2]).

qsort(_, []) -> [];
qsort(P, [Pivot|TL]) ->
  qsort(P, [X||X<-TL, P(X,Pivot)]) ++ [Pivot] ++  qsort(P, [X||X<-TL, not P(X,Pivot)]).
```

```
-module(prime).
-export([primes/1]).

primes(N) when N>1 -> [X|| X <- lists:seq(2,N),
   (length([Y || Y <- lists:seq(2, trunc(math:sqrt(X))), ((X rem Y) == 0)]) == 0)];
primes(_) -> [].
```

```
1> sort:qsort(fun(X, Y) -> X<Y end, [13, 1, -1, 8, 9, 0, 3.14]).
[-1, 0, 1, 3.14, 8, 9, 13]
2> sort:qsort(fun(X, Y) -> X>Y end, [13, 1, -1, 8, 9, 0, 3.14]).
[13, 9, 8, 3.14, 1, 0, -1]

3> prime:primes(100).
[2,3,5,7,11,13,17,19,23,29,31,37,41,43,47,53,59,61,67,71,73,79,83,89,97]
```


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