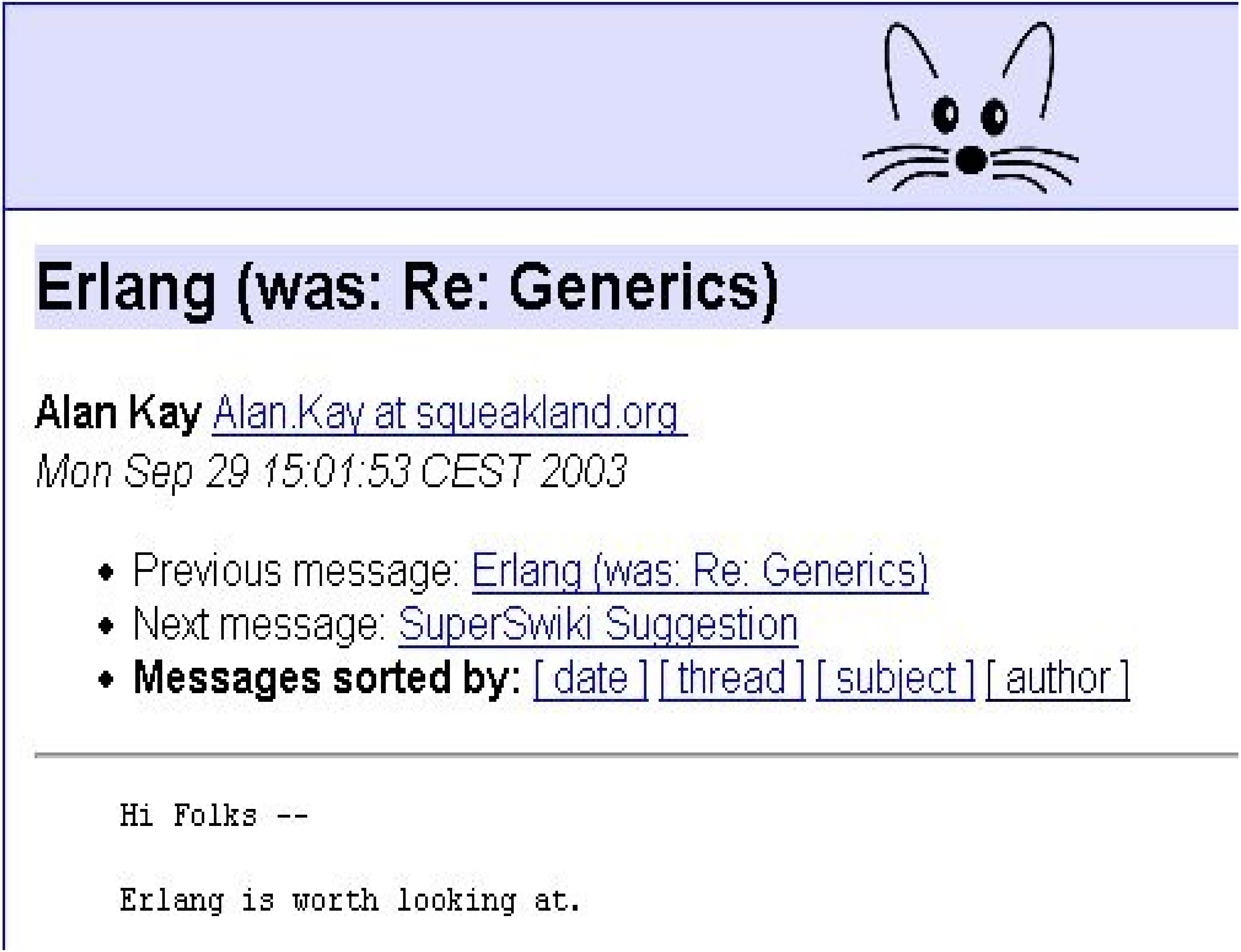
Erlang

Joe Armstrong



Erlang (was: Re: Generics)

Alan Kay Alan.Kay at squeakland.org
Mon Sep 29 15:01:53 CEST 2003

- Previous message: Erlang (was: Re: Generics)
- Next message: SuperSwiki Suggestion
- **Messages sorted by:** [date] [thread] [subject] [author]

```
Hi Folks --

Erlang is worth looking at.
```

Though OOP came from many motivations, two were central. The large scale one was to find a better module scheme for complex systems involving hiding of details, and the small scale one was to find a more flexible version of assignment, and then to try to eliminate it altogether.

...doing encapsulation right is a commitment not just to abstraction of state, but to eliminate state oriented metaphors from programming.

The Early History of Smalltalk
Alan Kay

```
for i in {objects, processes}
{
   create very large numbers of $i
   $i work the same way on all OS's
   $i's are garbage collected
   $i are location transparent
   $i cannot damage other $i
   $i are defined in the language
   creating and destroying $i is light-weight
}
```

Erlang is Smalltalk as Alan Kay wanted it

- Niall Dalton

How do we build systems that run forever, are scalable, fault-tolerant, evolve with time and work reasonably well works despite errors in the software?

Difficult

To make
a fault-tolerant system
you need at least

two

computers

this is

Distributed Programming

Simplify the problem

no sharing

pure message passing

no locks

This is

Concurrency Oriented Programming

Concurrency Oriented Programming

- *A style of programming where* concurrency is used to structure the application

- Large numbers of processes
- Complete isolation of processes
- No sharing of data
- Location transparency
- Pure message passing

> My first message is that concurrency
> is best regarded as a program
> structuring principle”
>
> Structured concurrent programming
> – Tony Hoare
> Redmond, July 2001

COP Design Rules

1) Identify the concurrent operations in your problem
2) Identify the message channels
3) Write down the set of message seen on each channel
4) Write down the protocols
5) Write the code

Try to make the design isomorphic to the problem – ie a 1:1 correspondence between the process/message structure in the model and the problem.

Who am I?

Inventor of Erlang, UBF
Chief designer of OTP
Founder of the company Bluetail

Currently
Senior System Architect
Ericsson AB

Current Interests
Concurrency Oriented Programming
Multi-core CPUs
FPGAs
Cats
Motorbikes

How do we correct hardware failures?

Replicate the hardware

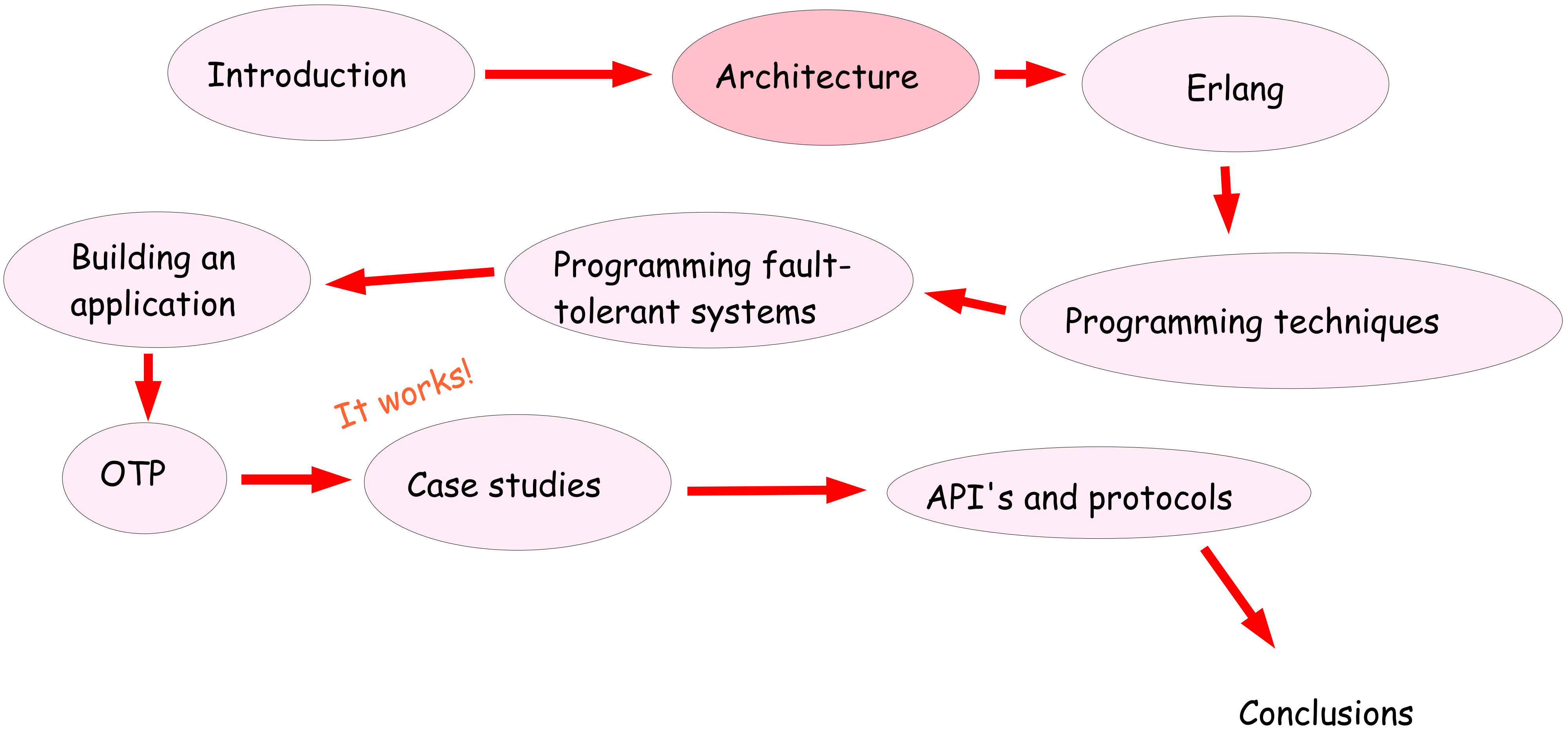
How do we correct software errors?

Having two identical copies of the software won't work – both will fail at the same time and for the same reason

Why does your computer crash?

Which fails more often, hardware or software?

Talk organisation



Introduction

Architecture

Erlang

Programming techniques

Programming fault-tolerant systems

Building an application

OTP

Case studies

API's and protocols

Conclusions

History

1986 – Pots Erlang (in Prolog)
1987 – ACS/Dunder
1988 – Erlang -> Strand (fails)
1989 – JAM (Joe's abstract machine)
1990 – Erlang syntax changes (70x faster)
1991 – Distribution
1992 – Mobility Server
1993 – Erlang Systems AB
1995 – AXE-N collapses. AXD starts
1996 – OTP starts
1998 – AXD deployed. Erlang Banned. Open Source Erlang.
Bluetail formed
1999 – BMR sold
2000 – Alteon buys Blutail. Nortel buys Alteon
2002 – UBF. Concurrency Oriented Programming
2003 – Ph.D. Thesis - Making reliable systems
2006 – Multi-core Erlang

How do we make systems?

Systems are made of black boxes (components)

Black boxes execute concurrently

Black boxes communicate

How the black box works internally is irrelevant

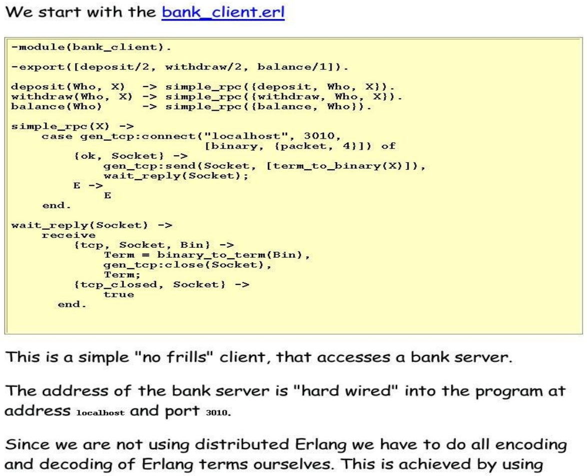
Failures inside one black box should not crash another black box

Problem domain

- Highly concurrent (hundreds of thousands of parallel activities)
- Real time
- Distributed
- High Availability (down times of minutes/year - never down)
- Complex software (million of lines of code)
- Continuous operation (years)
- Continuous evolution
- In service upgrade

Architecture

Philosophy
- Way of doing things
  - Construction Guidelines
    - Programming examples



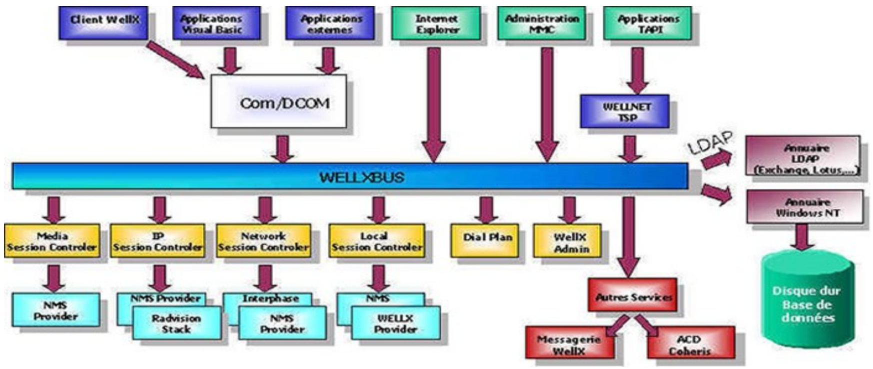
We start with the bank_client.erl

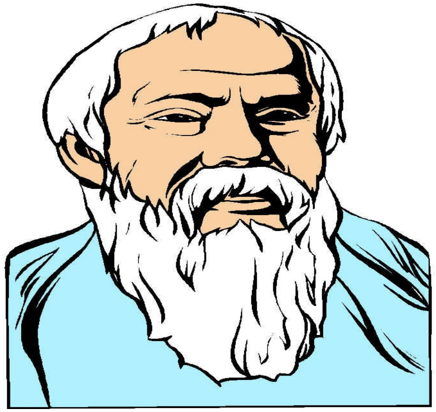
```
-module(bank_client).

-export([deposit/2, withdraw/2, balance/1]).

deposit(Who, X)  -> simple_rpc({deposit, Who, X}).
withdraw(Who, X) -> simple_rpc({withdraw, Who, X}).
balance(Who)     -> simple_rpc({balance, Who}).

simple_rpc(X) ->
    case gen_tcp:connect("localhost", 3010,
                         [binary, {packet, 4}]) of
        {ok, Socket} ->
            gen_tcp:send(Socket, [term_to_binary(X)]),
            wait_reply(Socket);
        E ->
            E
    end.

wait_reply(Socket) ->
    receive
        {tcp, Socket, Bin} ->
            Term = binary_to_term(Bin),
            gen_tcp:close(Socket),
            Term;
        {tcp_closed, Socket} ->
            true
      end.
```

This is a simple "no frills" client, that accesses a bank server.

The address of the bank server is "hard wired" into the program at address `localhost` and port `3010`.

Since we are not using distributed Erlang we have to do all encoding and decoding of Erlang terms ourselves. This is achieved by using





Philosophy

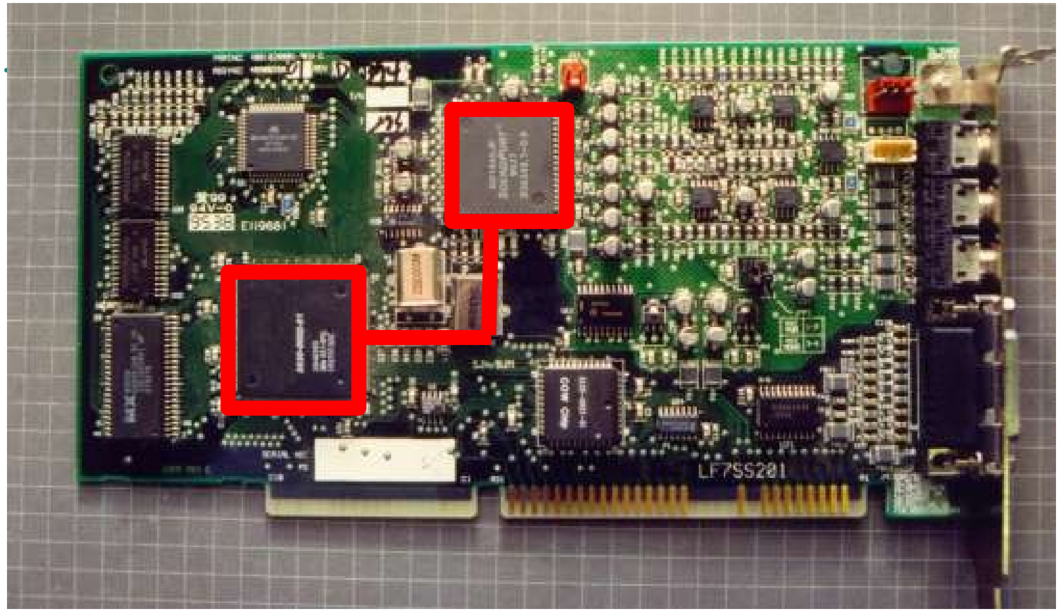
Concurrency Oriented Programming

1. COPLs support processes
2. Processes are Isolated
3. Each process has a unique unforgeable Id
4. There is no shared state between processes
5. Message passing is unreliable
6. It should be possible to detect failure in another processes and we should know the reason for failure

System requirements

R1. Concurrency	processes
R2. Error encapsulation	isolation
R3. Fault detection	what failed
R4. Fault identification	why it failed
R5. Live code upgrade	evolving systems
R6. Stable storage	crash recovery

Isolation



Hardware components operate concurrently are isolated and communicate by message passing

Consequences of Isolation

Processes have share nothing semantics and data must be copied

Message passing is the only way to exchange data

Message passing is asynchronous

GOOD STUFF

Processes

Copying

Message passing

Language

My program should not be able to crash your program
Need strong isolation and concurrency

Processes are OK - threads are not (threads have shared resources)

Can't use OS processes (Heavy - semantics depends on OS)

Isolation

My program should not be able to crash your program.

This is the single most important property that a system component must have

All things are not equally important

Erlang

Lightweight processes (lighter than OS threads)
Good isolation (not perfect yet ...)
Programs never loose control
Error detection primitives
Reason for failure is known
Exceptions
Garbage collected memory
Lots of processes
Functional

Agner Krarup Erlang (1878-1929)

Erlang in 11 minutes

Erlang

You can create a parallel process

```
Pid = spawn(fun() -> ... end).
```

then send it a message

```
Pid ! Msg
```

and then wait for a reply

```
receive
   {Pid, Rely} ->
        Actions
end
```

It typically takes 1 microsecond to
create a process or send a message

Processes are
isolated

Generalisation

Client

```
Pid = spawn(fun() -> loop() end)
Pid ! {self(), 21},
receive
    {Pid, Val} -> ...
end
```

Server

```
loop() ->
    receive
        {From, X} ->
            From ! {self(), 2*X},
            loop()
    end.
```

A simple process

Client

```
Double = fun(X) -> 2 *X end,
Pid = spawn(fun() -> loop(Double) end)
Pid ! {self(), 21},
receive
    {Pid, Val} -> ...
end
```

Server

```
loop(F) ->
    receive
        {From, X} ->
            From ! {self(), F(X)},
            loop(F)
    end.
```

Generalised

A generic server

```
-module(gserver).
-export([start/1, rpc/2, code_change/2]).

start(Fun) ->
    spawn(fun() -> loop(Fun) end).

rpc(Pid, Q) ->
    Pid ! {self(), Q},
    receive
        {Pid, Reply} ->
            Reply
    end.

code_change(Pid, Fun1) ->
    Pid ! {swap_code, Fun1}.
```

```
loop(F) ->
    receive
        {swap_code, F1} ->
            loop(F1);
        {Pid, X} ->
            Pid ! {self(), F(X)},
            loop(F);
    end.
```

```
Double = fun(X) -> 2*X end,
Pid = gserver:start(Double),
...
Triple = fun(X) -> 3*X end,
gserver:code_change(Pid, Triple)
```

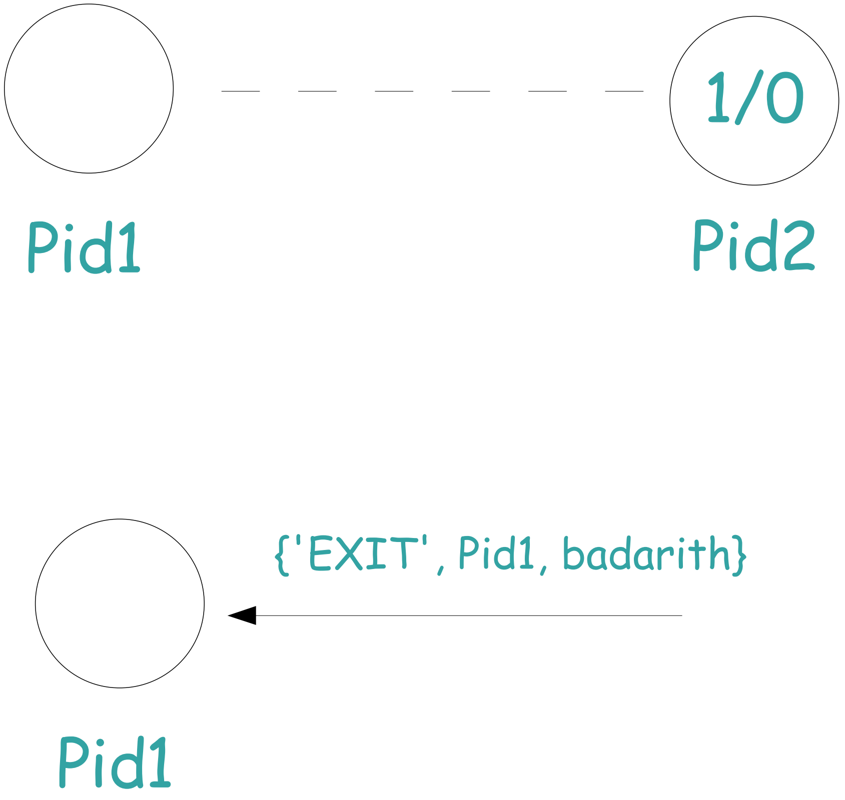
A generic server with data

```
-module(gserver).
-export([start/2, rpc/2, code_change/2]).

start(Fun, Data) ->
    spawn(fun() -> loop(Fun, Data) end).

rpc(Pid, Q) ->
    Pid ! {self(), Q},
    receive
        {Pid, Reply} ->
            Reply
    end.

code_change(Pid, Fun1) ->
    Pid ! {swap_code, Fun1}.
```

```
loop(F, Data) ->
    receive
        {swap_code, F1} ->
            loop(F1, Data);
        {Pid, X} ->
            {Reply, Data1} = F(X),
            Pid ! {self(), Reply},
            loop(F, Data1);
    end.
```

Trapping errors

```
In Pid1 ...
Pid2 = spawn_link(fun() -> ... end).
process_flag(trap_exit, true)
...

receive
	{'EXIT', Pid, Why} ->
		Actions
end.
```

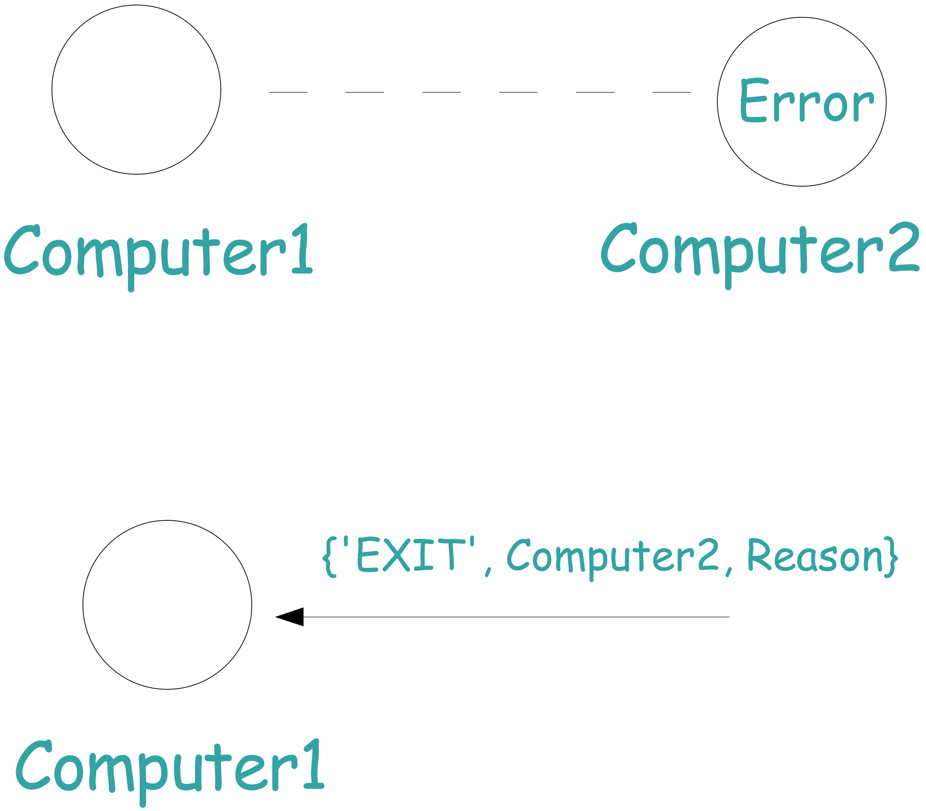


error detection + reason for failure (slide 10)

Why remote trapping of errors?

To do fault-tolerant computing you need at least TWO computers

Which means you can't share data



Error

Computer1

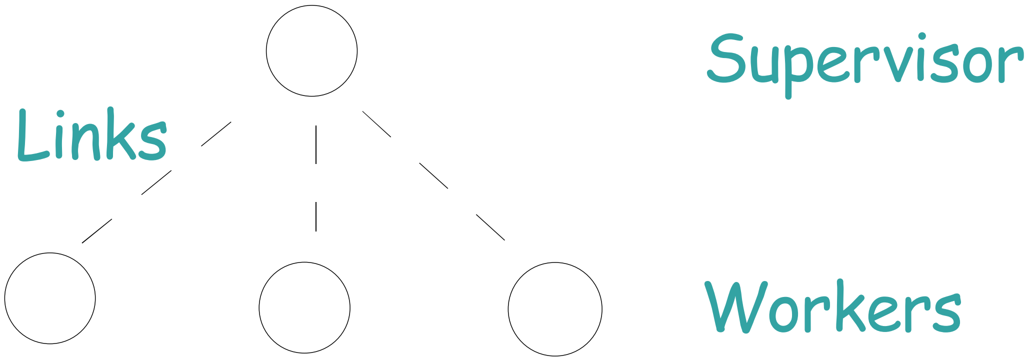
Computer2

{'EXIT', Computer2, Reason}

Computer1

Programming for errors

If you can't do what you want to do try and do something simpler



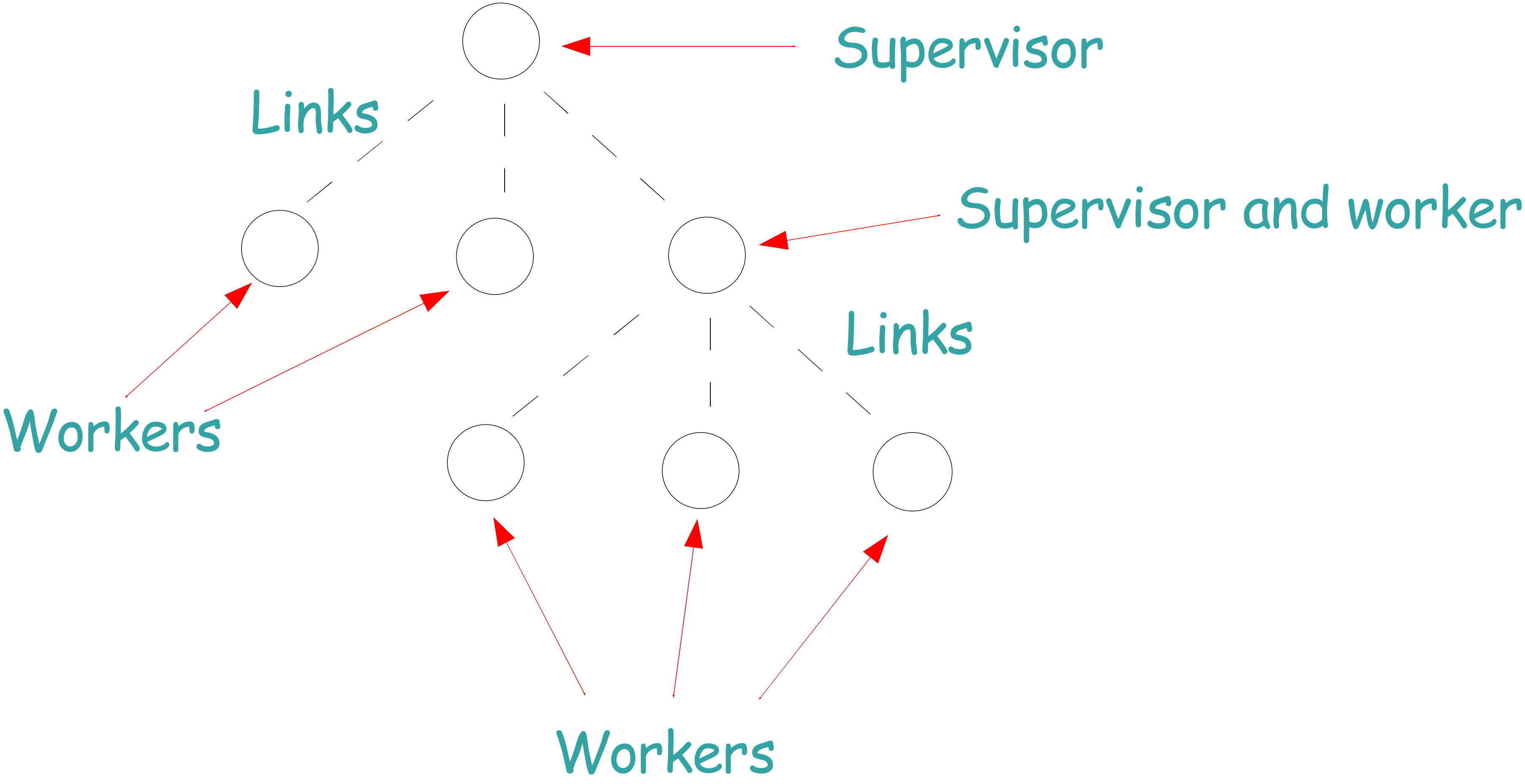
Links

Supervisor

Workers

The supervisor monitors the workers and restarts them if they fail

A supervision hierarchy



OTP behaviours

Generic libraries for building components of a real-time system.

Includes

Client-server
Finite State machine
Supervisor
Event Handler
Applications
Systems

case studies

Ericsson AXD301 (in Engine)

Size = 1136150 lines Erlang

Dirty functions = 0.359%

Availability = 99.9999999%

Alteon (Nortel) SSL accelerator

Size = 74440 line Erlang

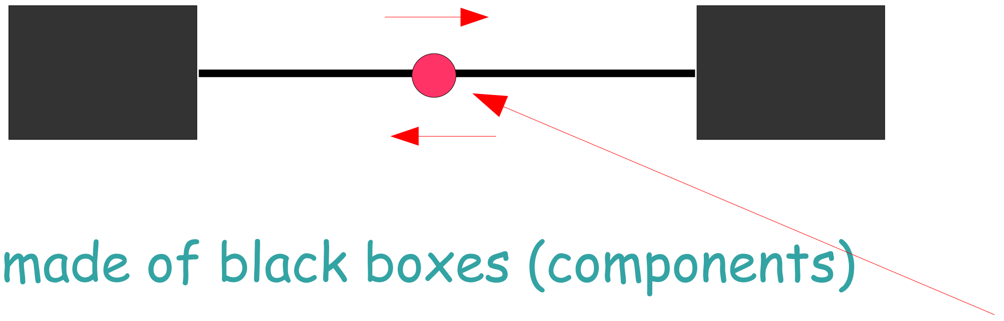
Dirty functions = 0.82%

Ref: Armstrong Ph.D. thesis

Commercial Successes

Ericsson AXD301 (part of "Engine")
Ericsson GPRS system
Alteon (Nortel) SSL accelerator
Alteon (Nortel) SSL VPN
Teba Bank (credit card system – South Africa)
T-mobile SMS system (UK)
Kreditor (Sweden)
jabber.org

How do we make systems?



Protocol checker

Systems are made of black boxes (components)

Black boxes execute concurrently

Black boxes communicate with defined (universal) protocols

The protocol is checked externally

How the black box works internally is irrelevant

APIs done wrong

```
+type file:open(fileName(), read | write) ->
      {ok, fileHandle()}
     | {error, string()}.

+type file:read_line(fileHandle()) ->
      {ok, string()} | eof.

+type file:close(fileHandle()) ->
      true.

+deftype fileName()   = [int()]
+deftype string()     = [int()].
+deftype fileHandle() = pid().
```

```
silly() ->
   {ok, H} = file:open("foo.dat", read),
   file:close(H),
   file:read_line(H).
```

APIs with state

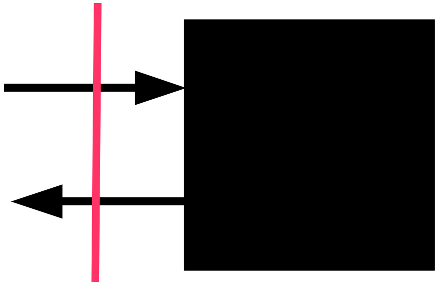
```
+type start x file:open(fileName(), read | write) ->
        {ok, fileHandle()} x ready
       | {error, string()}  x stop.

+type ready x file:read_line(fileHandle()) ->
            {ok, string()} x ready
          | eof x atEof.

+type atEof | ready x file:close(fileHandle()) ->
          true x stop.

+type atEof | ready x file:rewind(fileHandle()) ->
        true x ready.
```

```
silly() ->
   {ok, H} = file:open("foo.dat", read),
   file:close(H),
   file:read_line(H).
```

Protocols or APIs

```
+state start x {open, fileName(), read | write} ->
          {ok, fileHandle()} x ready
        | {error, string()}  x stop.

+state ready x {read_line, fileHandle()} ->
           {ok, string()} x ready
        | eof x atEof.

+state ready | atEof x {close, fileHandle()}->
   true x stop.

+state ready | atEof x {rewind, fileHandle()) ->
          true x ready
```

How things work inside the black box is irrelevant



Check the protocol at the boundaries to the black box

Finally

My program should not be able to crash your program.

This is the single most important property that a system component must have

All things are not equally important