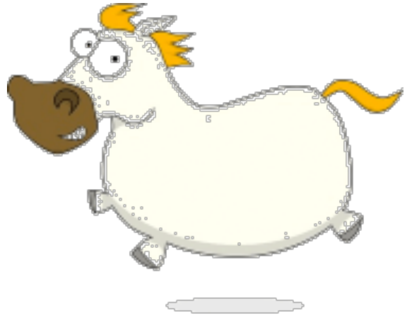
The Wide World of Almost-Actors: Can I Have an Erlang Pony?



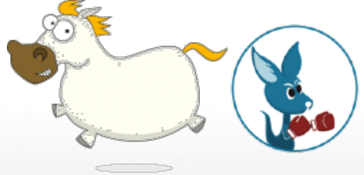
clojure.mn @ SPS Commerce

Wednesday, Aug 14, 2019

Scott Lystig Fritchie

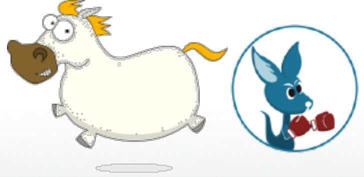
Wallaroo Labs

Introducing Myself



- I am Scott Lystig Fritchie
- Currently at Wallaroo Labs
- Formerly: VMware Research, Basho, Gemini Mobile, Caspian Networks, Sendmail, and UNIX sysadmin prior
    - 20 year Erlang anniversary
- @slfritchie at GitHub and Twitter
- I eat and cook a lot of Japanese food

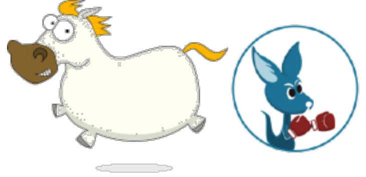
Outline of the Talk



- (= BEAM Actors)
  - False!
  - Input from y’all about actors in Clojure!
- Actor Model: defined & argued about
- Very brief overview to the Erlang & Pony languages
- 26 extra dimensions to the Actor Model
- Actor implementations: BEAM languages vs. Pony

My Goals For You

- Better understanding of what the Actor Model is
- Many dimensions to design & build an actor system
- BEAM & Pony are quite similar
    - … except where they aren’t
- Pony is interesting enough to learn more about



(= BEAM Actors)

false

The Actor Model: 2019’s View

1. The actor is the fundamental unit of computation
2. An actor has its own state: registers, memory, etc.
3. An actor can read & modify only its own state
    - It is **private state**: no other actor has any access
    - Global state (variables, registers,…) **does not exist**

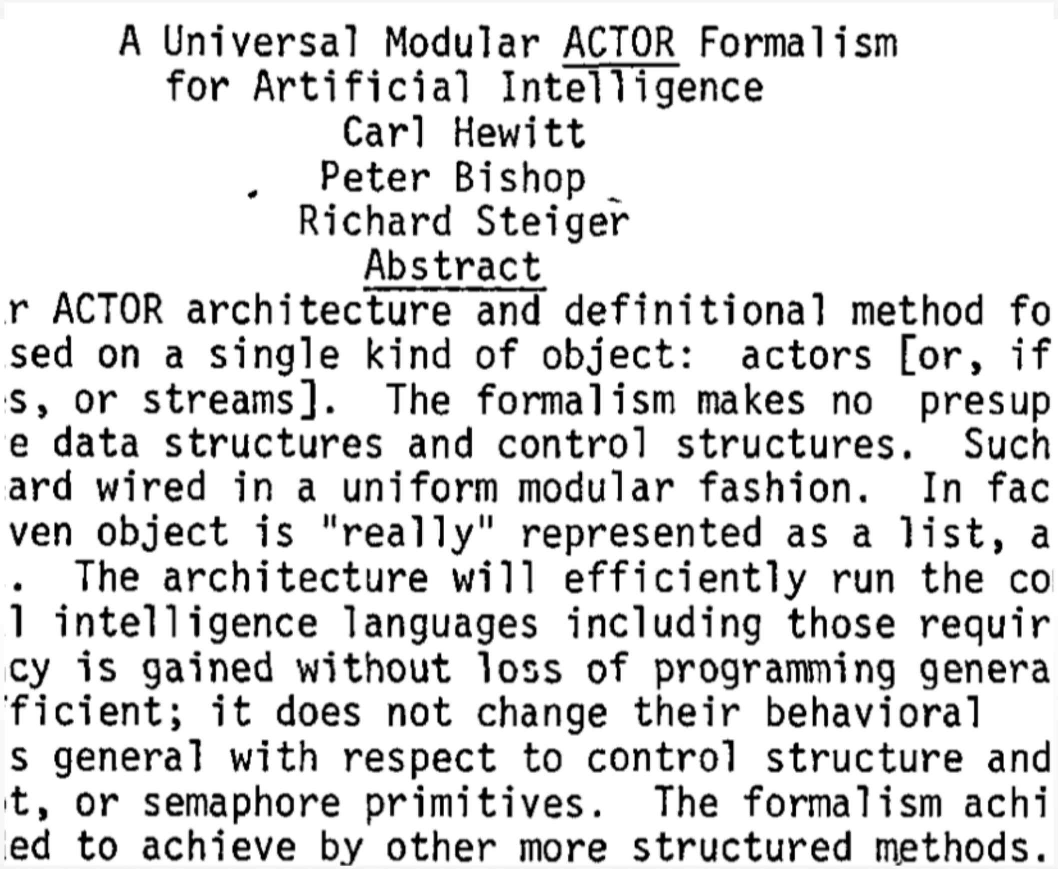
1. An actor can react to a message that was sent to it
2. An actor can create a new actor
3. An actor can send a message to another actor

Message passing is the only communication mechanism between actors.

Let’s Look at Actor History

First (?) Paper About Actors

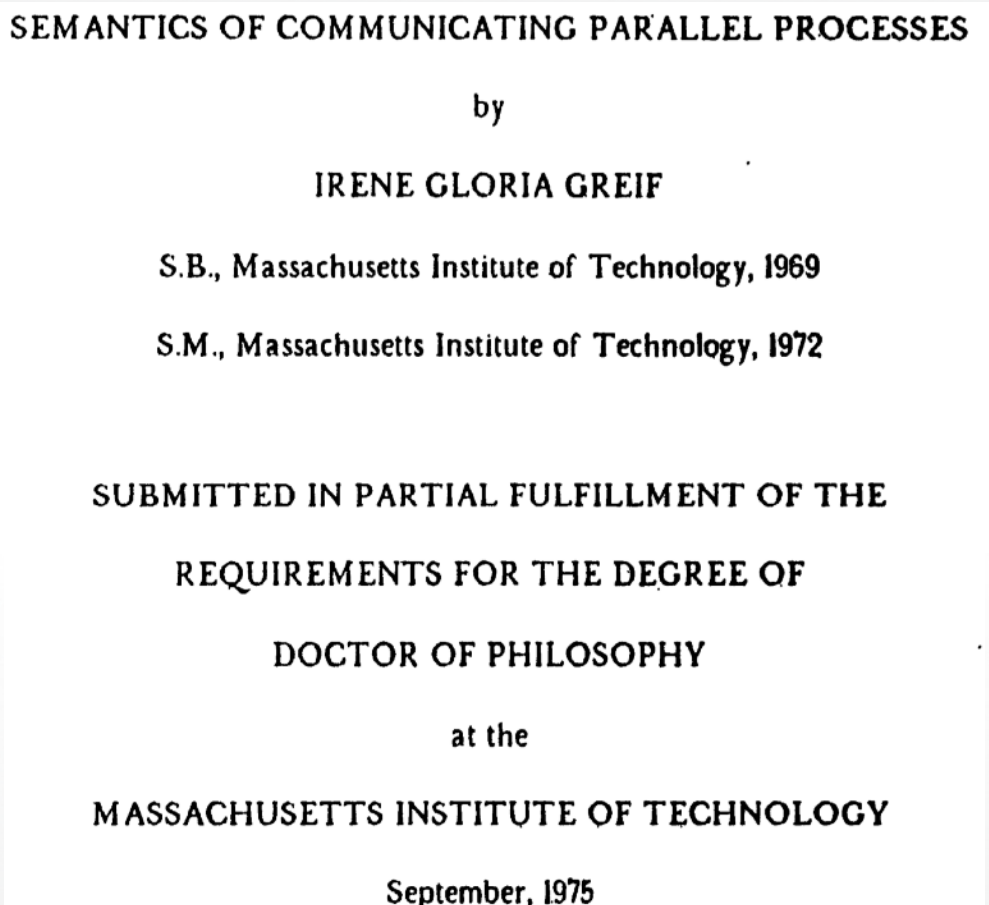
- Hewitt, Bishop, & Steiger, 1973


A Universal Modular ACTOR Formalism
for Artificial Intelligence
Carl Hewitt
Peter Bishop
Richard Steiger
Abstract

r ACTOR architecture and definitional method fo
sed on a single kind of object: actors [or, if
s, or streams]. The formalism makes no presup
e data structures and control structures. Such
ard wired in a uniform modular fashion. In fac
ven object is "really" represented as a list, a
. The architecture will efficiently run the co
l intelligence languages including those requir
cy is gained without loss of programming genera
ficient; it does not change their behavioral
s general with respect to control structure and
t, or semaphore primitives. The formalism achi
ed to achieve by other more structured methods.

Book About Actors

- Greif's Ph.D. Thesis, 1975



SEMANTICS OF COMMUNICATING PARALLEL PROCESSES

by

IRENE GLORIA GREIF

S.B., Massachusetts Institute of Technology, 1969

S.M., Massachusetts Institute of Technology, 1972

SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

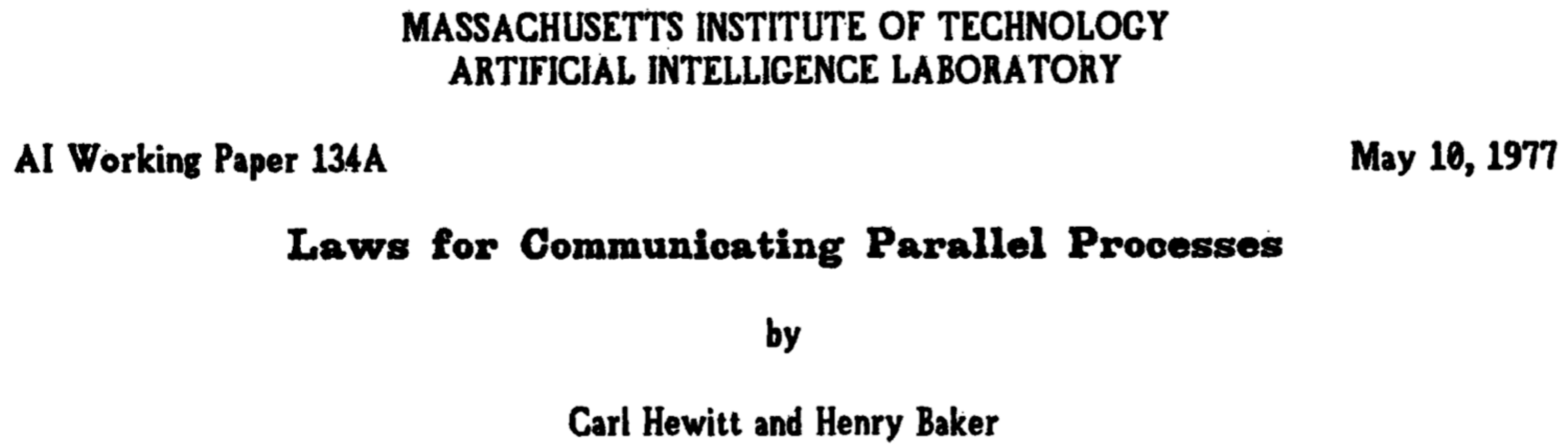
DOCTOR OF PHILOSOPHY

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September, 1975

Paper About Actors



MASSACHUSETTS INSTITUTE OF TECHNOLOGY
ARTIFICIAL INTELLIGENCE LABORATORY

AI Working Paper 134A May 10, 1977

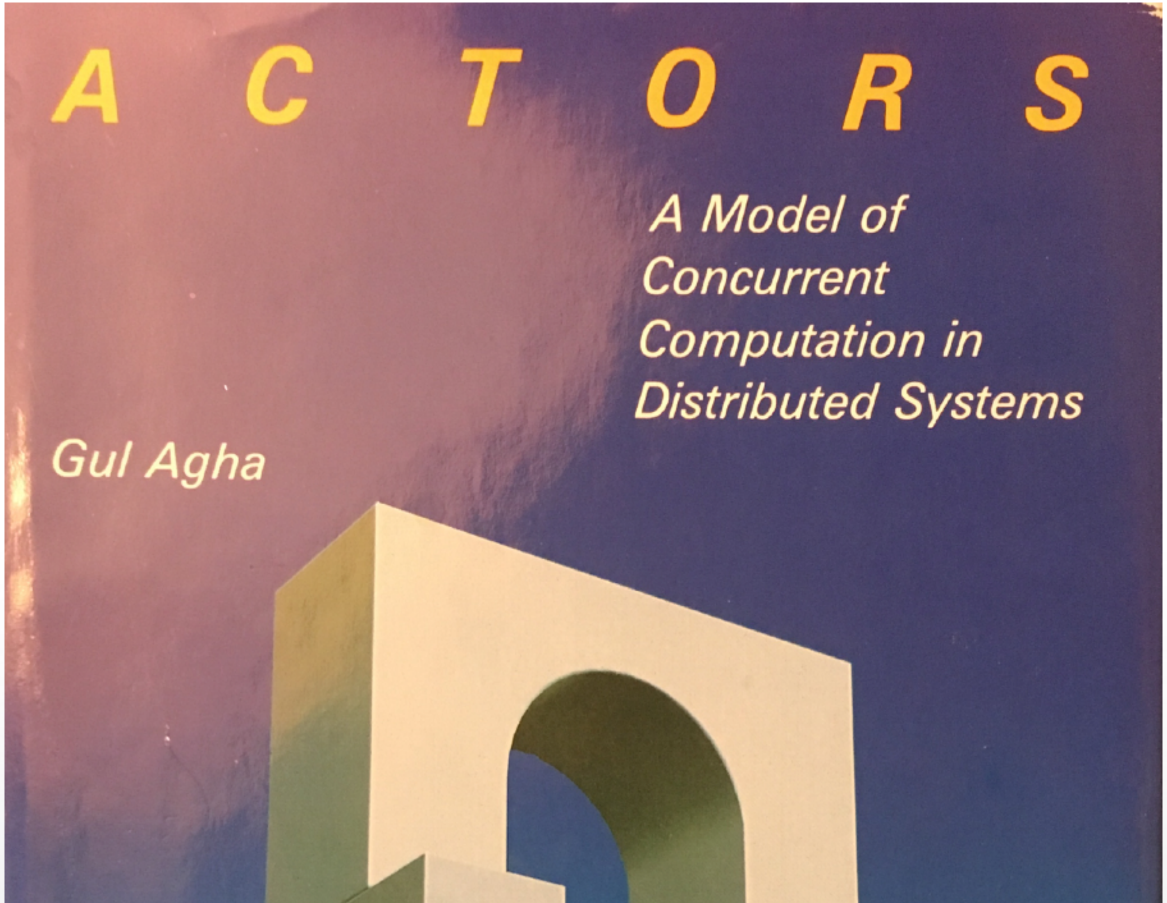
Laws for Communicating Parallel Processes

by

Carl Hewitt and Henry Baker

Book About Actors

- Agha, 1986

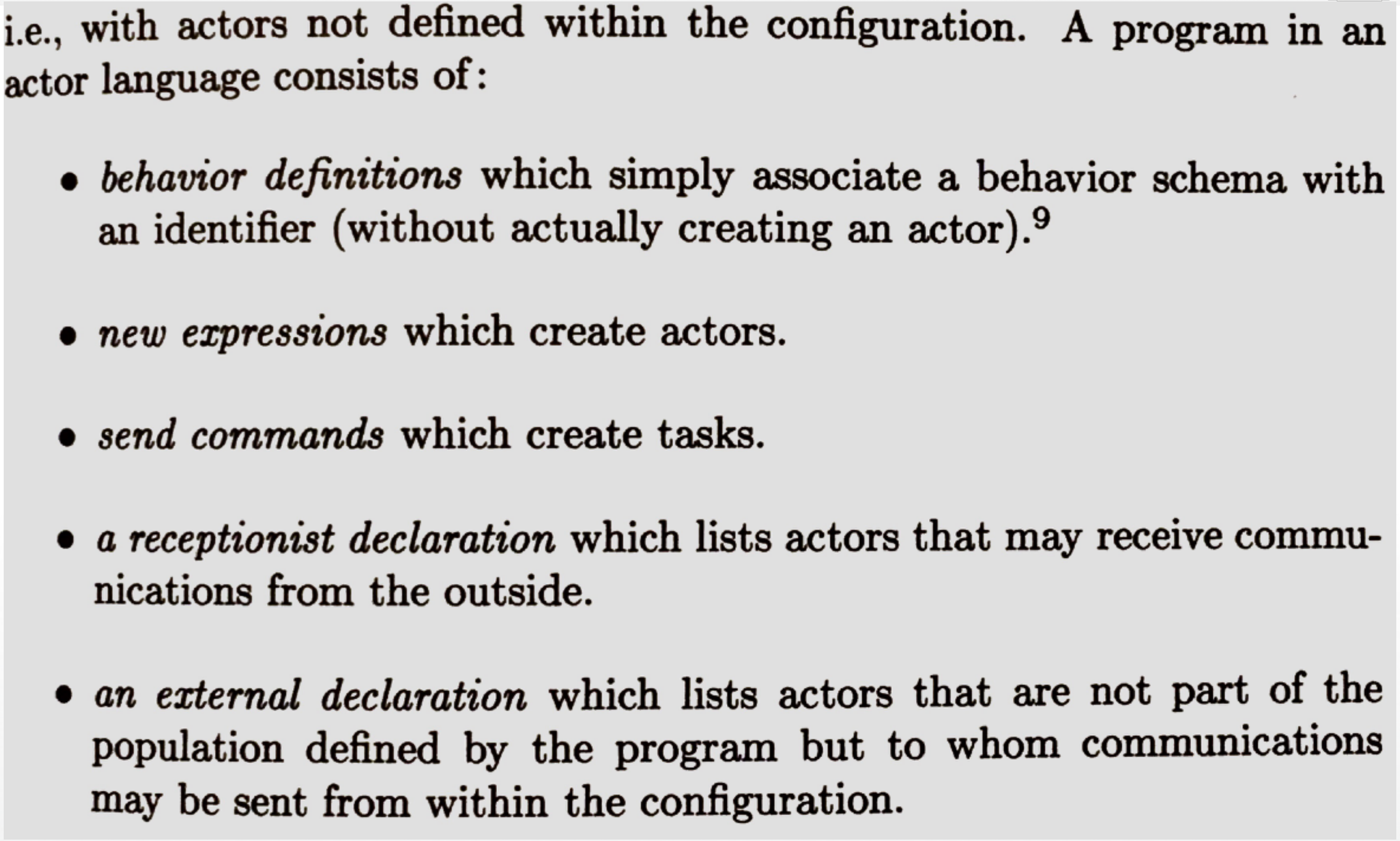


ACTORS

A Model of Concurrent Computation in Distributed Systems

Gul Agha

Agha's "Basic Constructs"



i.e., with actors not defined within the configuration. A program in an actor language consists of:

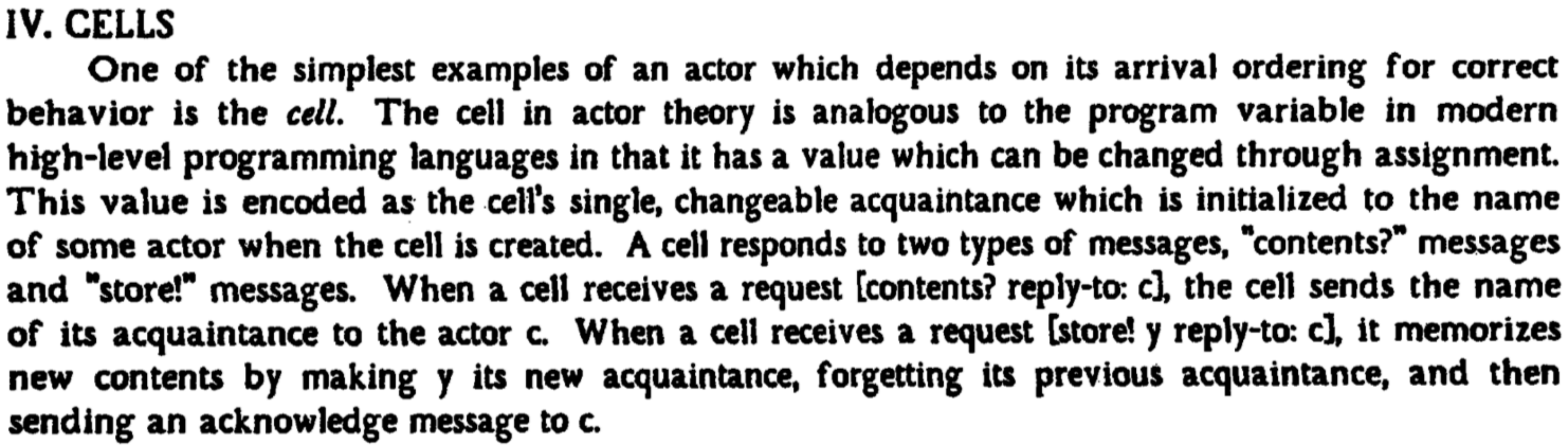
- *behavior definitions* which simply associate a behavior schema with an identifier (without actually creating an actor).[9]
- *new expressions* which create actors.
- *send commands* which create tasks.
- *a receptionist declaration* which lists actors that may receive communications from the outside.
- *an external declaration* which lists actors that are not part of the population defined by the program but to whom communications may be sent from within the configuration.

Actor Model Is Very General

The Actor Model differs from its predecessors and most current models of computation in that the Actor Model assumes the following:

- Concurrent execution in processing a message.
- The following are *not* required by an Actor: a thread, a mailbox, a message queue, its own operating system process, *etc*.[iv]
- Message passing has the same overhead as looping and procedure calling.
- Primitive Actors can be implemented in hardware.[i]

Cells Are Actors (1977)



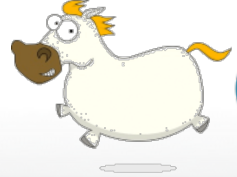
IV. CELLS

One of the simplest examples of an actor which depends on its arrival ordering for correct behavior is the *cell*. The cell in actor theory is analogous to the program variable in modern high-level programming languages in that it has a value which can be changed through assignment. This value is encoded as the cell's single, changeable acquaintance which is initialized to the name of some actor when the cell is created. A cell responds to two types of messages, "contents?" messages and "store!" messages. When a cell receives a request [contents? reply-to: c], the cell sends the name of its acquaintance to the actor c. When a cell receives a request [store! y reply-to: c], it memorizes new contents by making y its new acquaintance, forgetting its previous acquaintance, and then sending an acknowledge message to c.

Retrospective papers

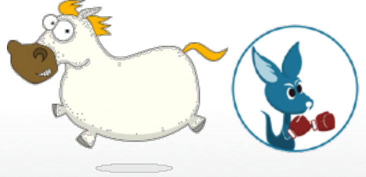
- Ten Years of Analyzing Actors: Rebeca Experience
  - Marjan Sirjani & Mohammad Mahdi Jaghoori
- 43 Years of Actors: A Taxonomy of Actor Models and Their Key Properties
  - Joeri De Koster, Tom Van Cutsem, & Wolfgang De Meuter
- History of Actors
  - Tony Garnock-Jones

Hasty Overview of Erlang



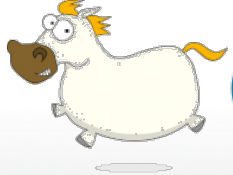
- Functional programming language
  - bound vs. unbound variable
- A program is divided into processes
  - Process = actor’ish thing = “green thread”
- A process can crash
- There are no global variables
  - … though cheating is possible
- All comm’s between processes is **async** message passing
  - … though cheating is possible
- Each process has a “mailbox” to queue msgs not received yet

Basic Sequential Erlang



```
%% Bound vs. unbound variables

X  = 42.         % X is now bound
Y  = 6.          % Y is now bound
X  = X + Y.      % X is bound, 42 /= 48, CRASH!
X2 = X + Y.      % X’s “new” val => different name
```

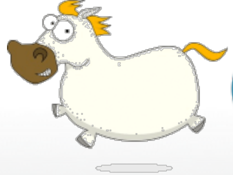
Basic Sequential Erlang



```
my_loop1(N) when N < 10 ->
    io:format(“Hello, N is %d\n”, [N]),
    my_loop1(N + 1);
my_loop1(N) ->
    ok.          % End of loop

my_loop2(10) ->
    ok;          % End of loop
my_loop2(N) ->
    io:format(“Hello, N is %d\n”, [N]),
    my_loop2(N + 1).
```

```
my_loop1(0).
my_loop1(-12).
my_loop1(12).
my_loop1(“7”).
```

Basic Sequential Erlang

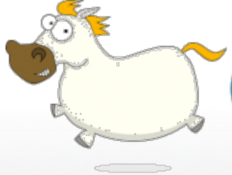


```
my_loop3(N) ->
    case N of
        99988877766655544433322211100099988877766 ->
            ok;
        _ ->                          % _ is wildcard pattern
            io:format(“Hello, N is %d\n”, [N]),
            my_loop1(N + 1)
    end.
```

Basic Sequential Erlang

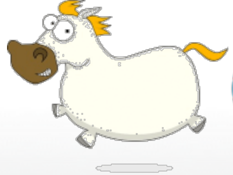
```
my_loop4(N) ->
    Seq = lists:seq(1, 10), % list [1,2,…,9,10]
    [io:format(“Hi, N = %d\n”, [N]) || N <- Seq].
```

Basic Message Passing in Erlang



```
Pid = spawn(…yo…). %% We create a new process
Answer = 7.
Pid ! Answer.
Pid ! {Answer, 43}.

yo() ->
    receive
        M ->
            io:format(“Message = ~p\n”, [M])
    end,
    yo().
Message = 7
Message = {7, 43}
```

Basic Message Passing in Erlang

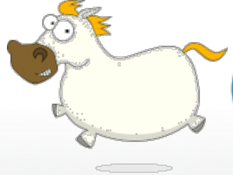


```
Pid = spawn(…yo…).  %% We create a new process
Pid ! 7.            %% Never handled by Pid
Pid ! {7, 43}.

yo() ->
    receive
        {G, B} ->
            io:format(“Yes = ~p, No = \n”, [G, B])
    end,
    yo().

Yes = 7, No = 43
```

Basic Message Passing in Erlang

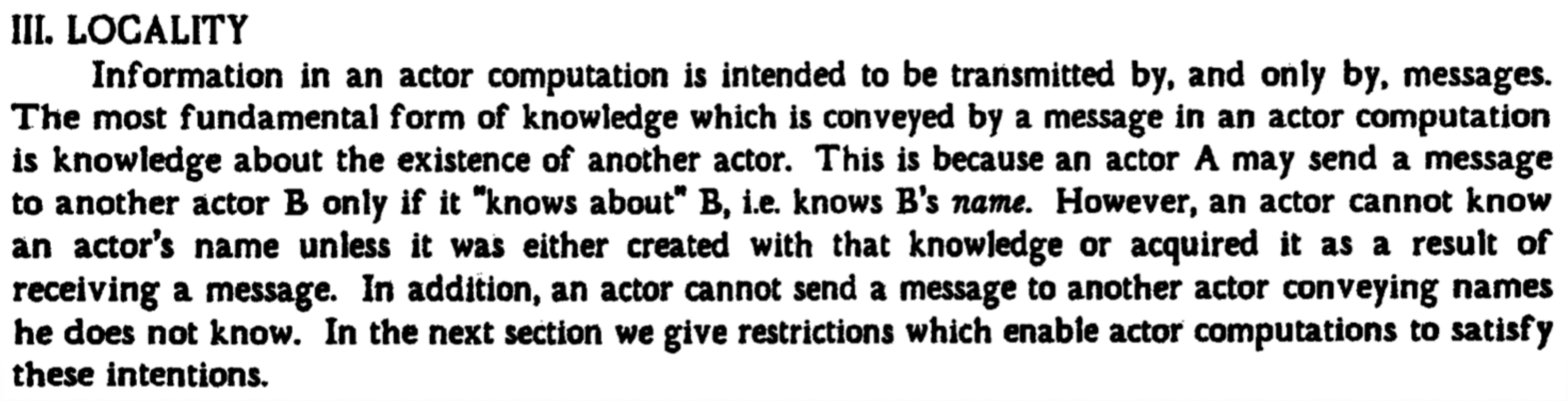
```
yo() ->
    Magic = 8,
    receive
        {G, B} ->
            io:format(“Yes = ~p, No = \n”, [G, B]);
        Magic ->
            io:format(“Got the magic number!\n”);
        Else ->
            io:format(“Got unknown: ~p\n”, [Else])
    end,
    yo().
```

Basic Message Passing in Erlang



```
yo() ->
   receive
        {G, B} ->
            io:format(“Yes = ~p, No = \n”, [G, B]),
            yo();
    after 5000 ->
            io:format(“5 second timeout!\n”)
            %% Looping ends here
    end.
```

Locality: Names Are Special



III. LOCALITY

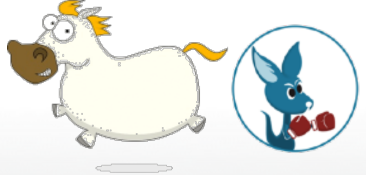
Information in an actor computation is intended to be transmitted by, and only by, messages. The most fundamental form of knowledge which is conveyed by a message in an actor computation is knowledge about the existence of another actor. This is because an actor A may send a message to another actor B only if it "knows about" B, i.e. knows B's *name*. However, an actor cannot know an actor's name unless it was either created with that knowledge or acquired it as a result of receiving a message. In addition, an actor cannot send a message to another actor conveying names he does not know. In the next section we give restrictions which enable actor computations to satisfy these intentions.

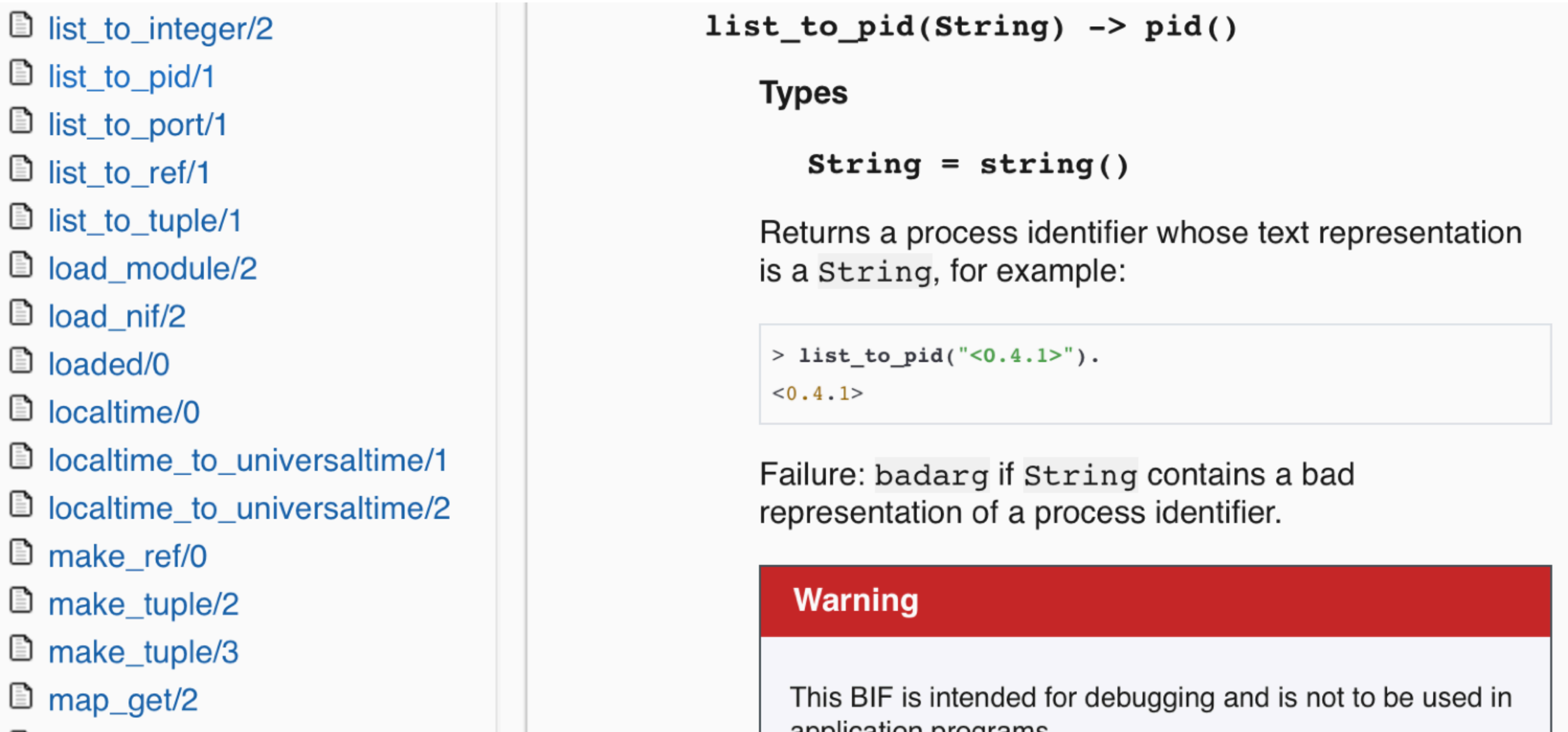
Locality: Names Are Special

Locality and security mean that in processing a message: an Actor can send messages only to addresses for which it has information by the following means:

1. that it receives in the message
2. that it already had before it received the message
3. that it creates while processing the message.

Forbidden to (Real) Actors!





- list_to_integer/2
- list_to_pid/1
- list_to_port/1
- list_to_ref/1
- list_to_tuple/1
- load_module/2
- load_nif/2
- loaded/0
- localtime/0
- localtime_to_universaltime/1
- localtime_to_universaltime/2
- make_ref/0
- make_tuple/2
- make_tuple/3
- map_get/2

```
list_to_pid(String) -> pid()
```

Types

```
String = string()
```

Returns a process identifier whose text representation is a `String`, for example:

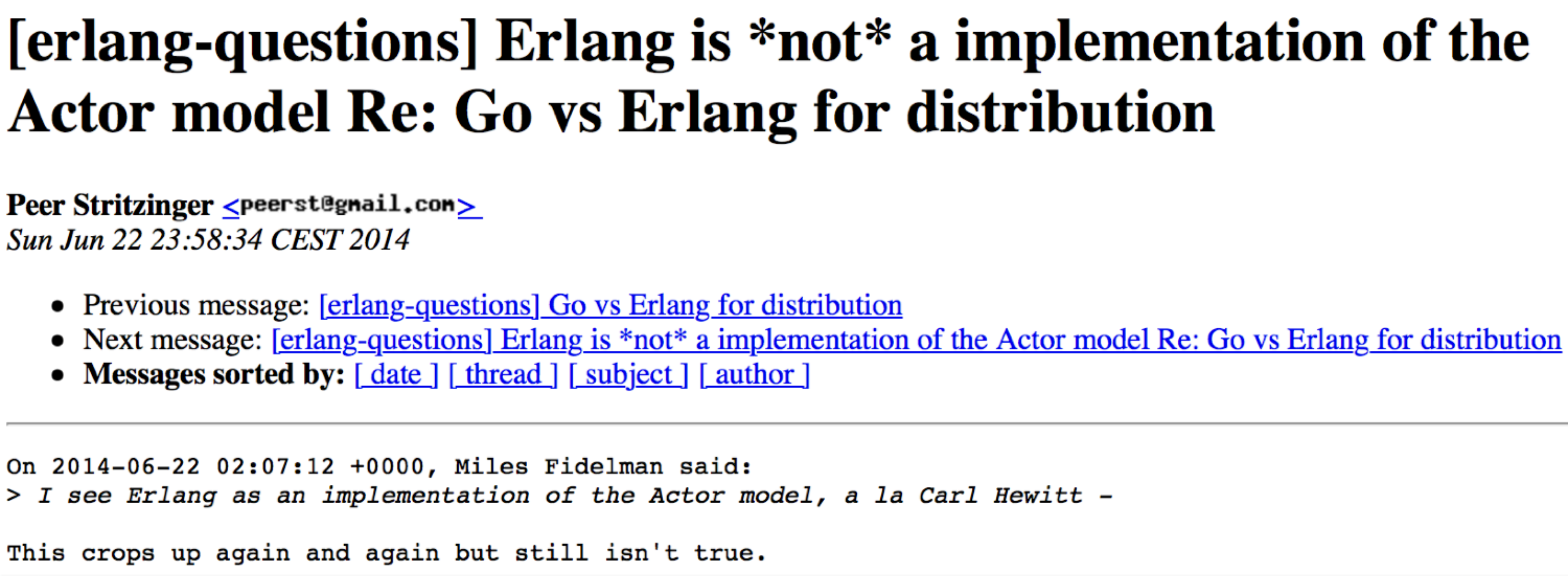
```
> list_to_pid("<0.4.1>").
<0.4.1>
```

Failure: `badarg` if `String` contains a bad representation of a process identifier.

Warning

This BIF is intended for debugging and is not to be used in application programs.

Erlang's Other Differences with Actors



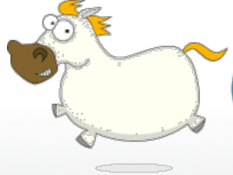
[erlang-questions] Erlang is *not* a implementation of the Actor model Re: Go vs Erlang for distribution

Peer Stritzinger <peerst@gmail.com>
Sun Jun 22 23:58:34 CEST 2014

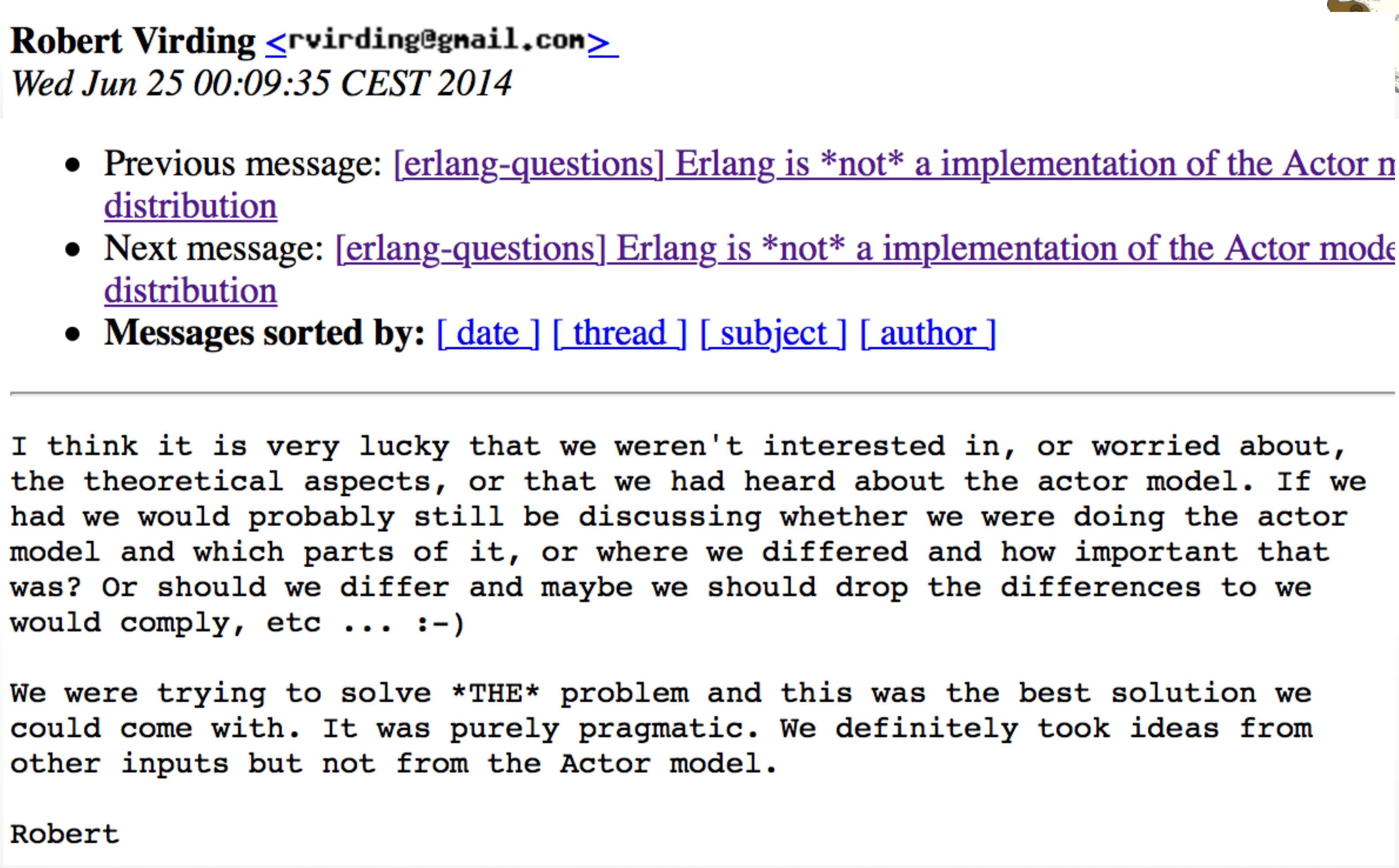
- Previous message: [erlang-questions] Go vs Erlang for distribution
- Next message: [erlang-questions] Erlang is *not* a implementation of the Actor model Re: Go vs Erlang for distribution
- **Messages sorted by:** [date] [thread] [subject] [author]

```
On 2014-06-22 02:07:12 +0000, Miles Fidelman said:
> I see Erlang as an implementation of the Actor model, a la Carl Hewitt -

This crops up again and again but still isn't true.
```

Arguing That Erlang /= Actors



- Selective receive reorders message delivery
- Process links that kill processes is very un-actor'ish
    - Monitors also
- Preemptive scheduling
- Actors must use Messaging exceptions, not die
    - without exception?
- No garbage collection of inactive actors



Robert Virding <rvirding@gmail.com>
Wed Jun 25 00:09:35 CEST 2014

- Previous message: [erlang-questions] Erlang is *not* a implementation of the Actor m distribution
- Next message: [erlang-questions] Erlang is *not* a implementation of the Actor mode distribution
- **Messages sorted by:** [date] [thread] [subject] [author]

```
I think it is very lucky that we weren't interested in, or worried about,
the theoretical aspects, or that we had heard about the actor model. If we
had we would probably still be discussing whether we were doing the actor
model and which parts of it, or where we differed and how important that
was? Or should we differ and maybe we should drop the differences to we
would comply, etc ... :-)

We were trying to solve *THE* problem and this was the best solution we
could come with. It was purely pragmatic. We definitely took ideas from
other inputs but not from the Actor model.

Robert
```

Agha's "Insensitive Actor" can buffer messages while waiting for a particular message (page 54)

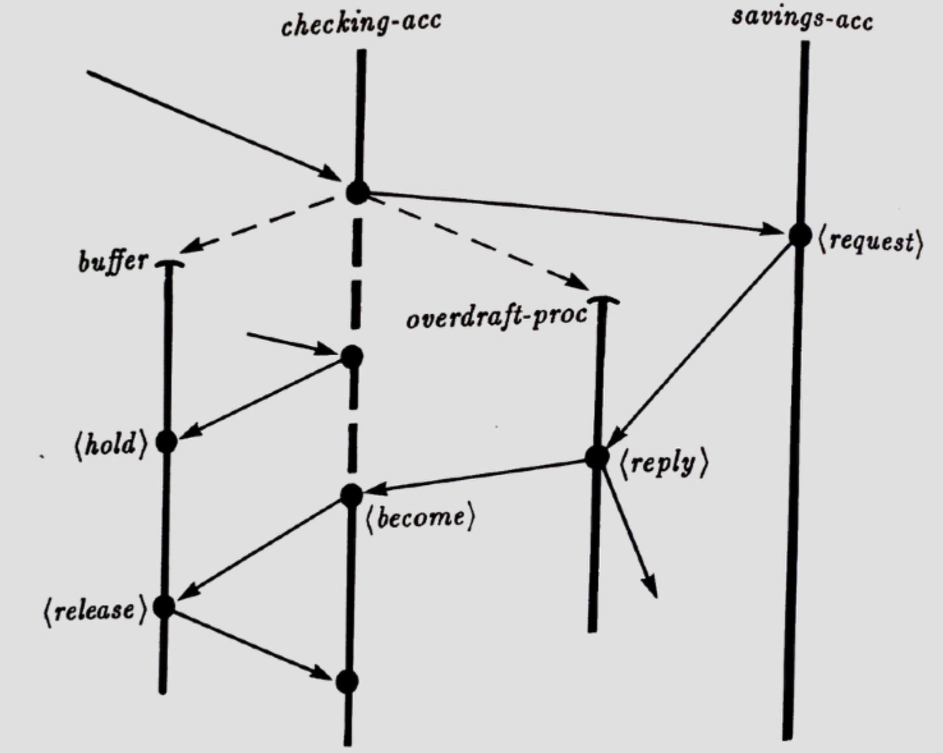
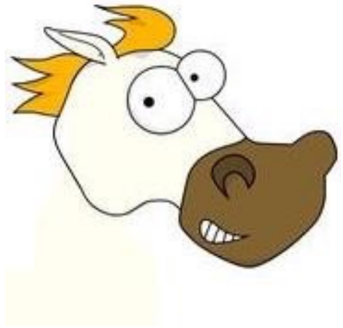
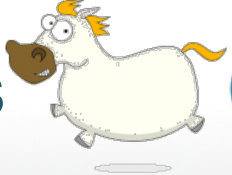


Figure 4.4: *Insensitive behaviors provide a mechanism for locking an actor. An insensitive actor continues to receive communications and may respond to some kinds of communications while buffering others. Specifically, during the dashed segment the insensitive checking account buffers any requests for checking transactions it receives.*

What is Pony?

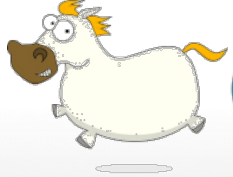


Pony language & runtime safety guarantees



- Type system is fully aware of actors types & concurrency
- Type safe
- Memory safe
- Exception safe
- “If it compiles, it is data-race free.”
- All messaging is pass-by-reference
- Sharing data between actors is guaranteed safe

Pony compiles to target hardware CPU



- Erlang, Elixir, LFE, etc.
  - Runs on BEAM VM with optional compilation to native code via HiPE
- Pony
  - Compiles to native code via LLVM toolchain
  - DWARF symbols, “looks like C++” to debuggers and profilers

Side-Effect of Exception Safety

- Pony actors do not crash
- All errors must be handled explicitly
    - “?” syntax used to mark a "partial function”
        - "partial" = "may raise an error"
- Compiler enforced, of course
- No actor crashes => no (?) need for BEAM’s links & monitors to help manage failure

Per-Actor Heaps + Distributed GC

- Distributed GC across all actor heaps
  - No "stop the world" GC
  - Fully concurrent: no sync, no locks, and no barriers (except as needed for lock-free data structures)
- Message passing maintains ref counts on shared objects
  - Dead objects are reaped by allocating actor
- GC and Type System **Co-Designed** with ORCA protocol
  - Actors are 1st class, GC’ed objects in the system
  - Runtime halts when all actors are GC’ed

Can I have an Erlang Pony?

Let's get more specific about what an actor implementation might really need

Actor’ish Design & Implementation Topics

1. Message sending
    - Synchronous? Named? Typed? …
2. Message receiving
    - Reliable? Order? Blocking? Time? …
3. Scheduling
    - Preemptive? Priorities? Resource limits? …
4. Message delivery guarantees
    - Academic distributed systems people want to know!
5. Actor lifetime? Run forever? Byzantine? …

BEAM languages vs. Pony

26 Dimensions of Actor-Flavored Models

Message Sending

Synchronous vs. Asynchronous message sending

- BEAM: async
- Pony: async

SAME

Message Sending

Named Processes vs. Unnamed Processes

- BEAM: named
- Pony: named

SIMILAR

Message Sending

What is a Message’s Destination?

- BEAM: one process
- Pony: one actor

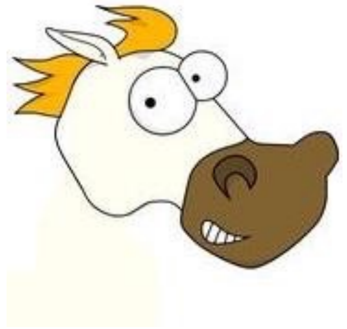
SAME

Message Sending

Typed vs. Untyped Messages

- BEAM: untyped
- Pony: typed

WHOA!

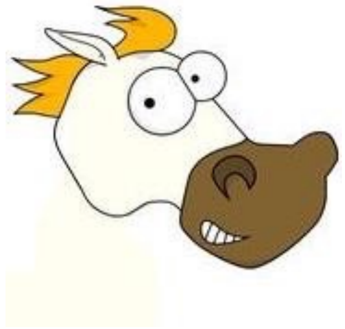


Message Sending

How does data appear in a mailbox?

- BEAM: copy to destination heap
- Pony: ref-counted pointers + distributed GC via ORCA protocol

WHOA!



Message Receiving

Reliable vs. Unreliable Delivery

- BEAM: reliable’ish
- Pony: reliable

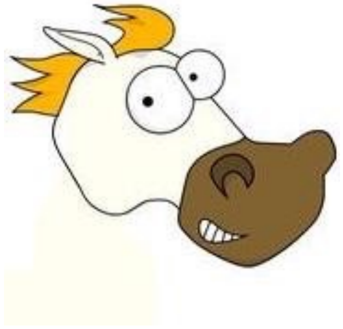
SIMILAR

Message Receiving

Message delivery order

- BEAM: any order
- Pony: FIFO only

WHOA!



Message Receiving

Causal message order guarantee

- BEAM: yes or no
- Pony: yes always

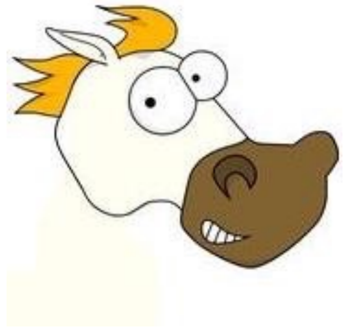
SIMILAR

Message Receiving

Blocking vs. Non-Blocking
message receive

- BEAM: yes
- Pony: no

WHOA!

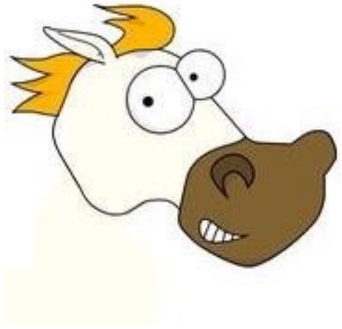


Message Receiving

Time-Aware vs. Time-Ignorant

- BEAM: yes
- Pony: no

WHOA!



Scheduling

What schedules actors?

- BEAM: custom scheduler
  - 1 scheduler/CPU core
- Pony: custom scheduler
  - 1 scheduler/CPU core

SAME

Scheduling

Scheduler Overhead

- BEAM: {100’s} bytes/process, {few} usec to create & destroy
- Pony: 240 bytes/actor, {few} usec to create & destroy
- Scheduling millions is fine
- Processes & Actors are cheap

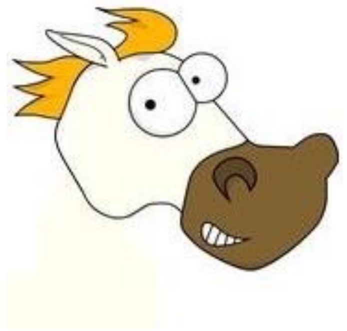
SAME

Scheduling

Preemptive vs. Cooperative Scheduling

- BEAM: Preemptive
- Pony: Cooperative

WHOA!

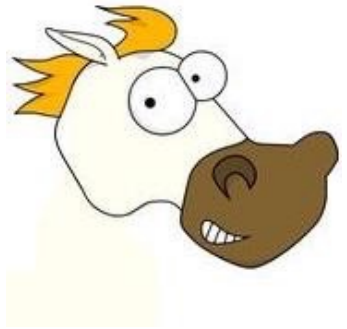


Scheduling

Actor priority schemes?

- BEAM: Yes, 4 levels
- Pony: No

WHOA!



Scheduling

Work stealing?

- BEAM: Yes
- Pony: Yes

SAME

Scheduling

Energy Conservation by Idle Schedulers?

- BEAM: Yes
- Pony: Yes

SAME

Scheduling

Mailbox size limits?

- BEAM: No
- Pony: No

SAME

Scheduling

Maximum Heap Size?

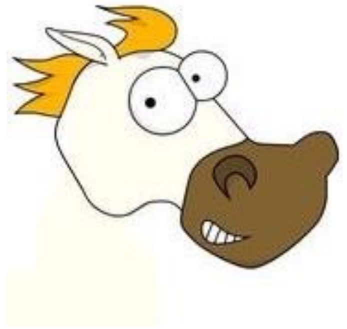
- BEAM: No
- Pony: No

SAME

Scheduling

- Actor Lifecycle
  - Cheap vs. Cheap *SAME*
- Actor Crash?
  - Yes vs. No

WHOA!

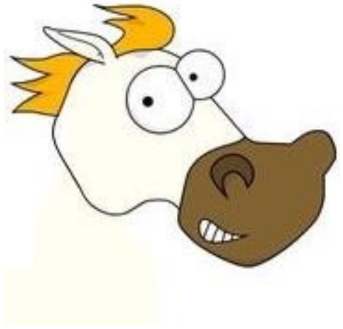


Scheduling

Back-pressure to reduce workload of overloaded actors?

- BEAM: No
- Pony: Yes

WHOA!

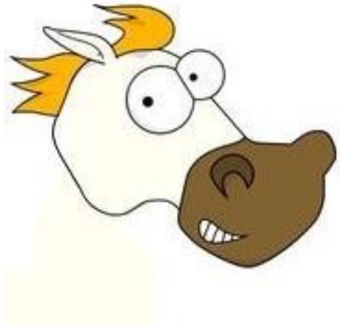


Theoretical Message Delivery Properties

- Causal order: Yes
  - *SIMILAR*
- - Message loss: 0%
  - *SAME*
- - Message duplication: 0%
  - *SAME*
- - Message reordering:

  WHOA!

WHOA!



Actors & the Outside World

Actor interaction with non-actors

- BEAM: yes
- Pony: yes, but…

SIMILAR

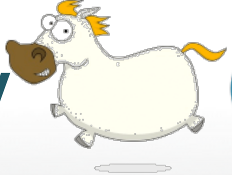
Byzantine Actors

Incorrect/Malicious Actors/
Corrupted Messages Allowed?

- BEAM: No
- Pony: No

SAME

Review of Similarities by Category



- SAME
  - 13
- SIMILAR
  - 5
- WHOA!
  - 9

WHOA! Summary

- Msg Receiving: message reordering
- Msg Receiving: blocking vs. non-blocking receive
- Msg Receiving: time-aware vs. time-ignorant
- Scheduling: preemptive vs. cooperative scheduling
- Msg Sending: untyped vs. typed messages
- Msg Sending: copy messages vs. shared pointers
- Scheduling: actor priority schemes?
- Lifecycle: actors crash?
- Back-pressure for "overloaded" actors?

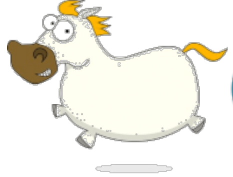
In Pony, one does not simply call() a gen_server

ever.

In Pony, one does not simply call() a gen_server

you cannot block awaiting for the reply.

In Pony, all messaging is !()-style or cast-style



… but it’s possible to work around. Pony is fun!

Did I mention that Pony programs are usually really, really fast?

Sources & Where to Look For More

On the Actor Model and CSP:

- https://en.wikipedia.org/wiki/Actor_model
- https://en.wikipedia.org/wiki/Communicating_sequential_processes

On Pony:

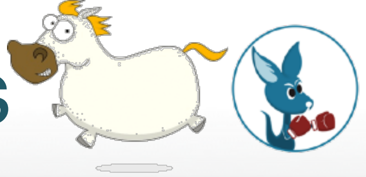
- http://ponylang.io (also Pony logo source)
- https://github.com/ponylang/ponyc/
- http://blog.acolyer.org/2016/02/17/deny-capabilities/
- https://blog.acolyer.org/2016/02/18/ownership-and-reference-counting-based-garbage-collection-in-the-actor-world/
- https://www.youtube.com/watch?v=e0197aoljGQ

Sean Bean image:
New Line Cinema, The Fellowship of the Ring, 2001
http://knowyourmeme.com/memes/one-does-not-simply-walk-into-mordor
https://memegenerator.net/Does-Not-Simply-Walk-Into-Mordor-Boromir

Wallaroo Lab's source repo for Wallaroo, a distributed stream processing system written in Pony:
https://github.com/WallarooLabs/wallaroo

Overflow slides

ORCA GC Comparison on µB'marks



72:20 S. Clebsch, J. Franco, S. Drossopoulou, A. M. Yang, T. Wrigstad, J. Vitek

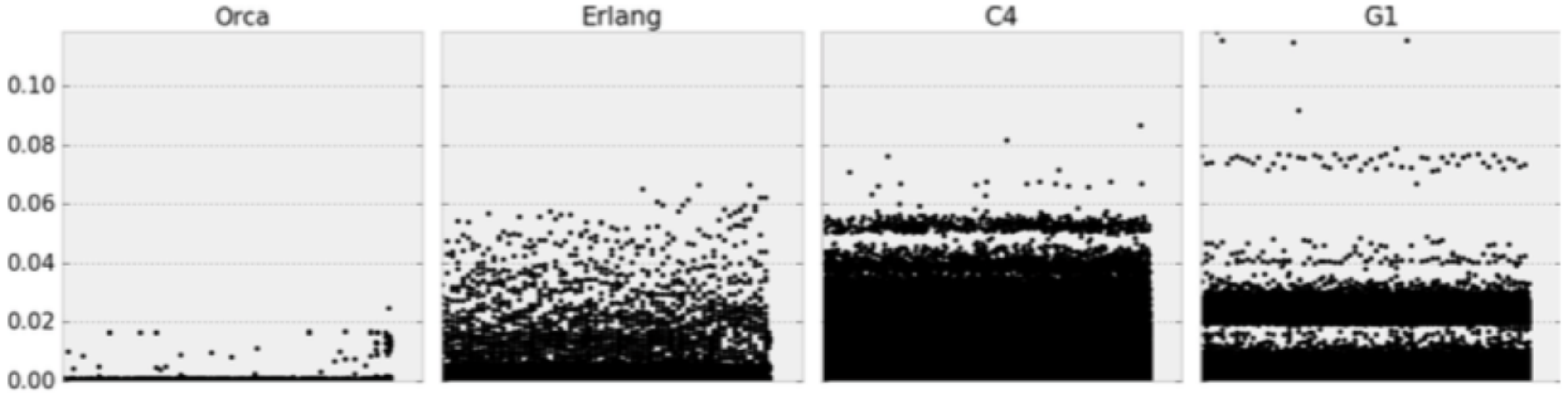
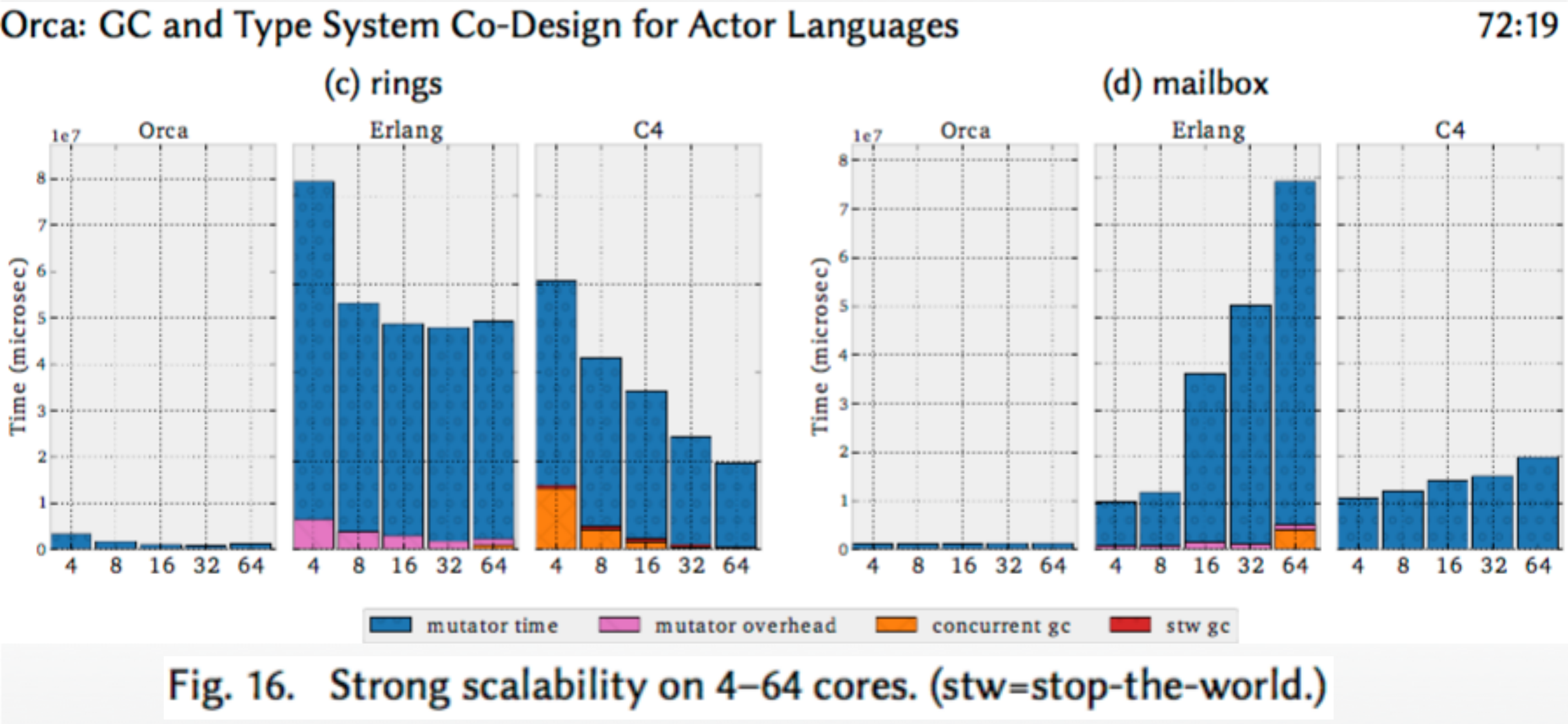


Fig. 17. Responsiveness. X-axis: request ID, Y-axis: Jitter/difference between finishing time (seconds) of subsequent requests. Java measurements are from a warmed-up VM and does not include JIT'ing.

ORCA GC Comparison on µB'marks



Orca: GC and Type System Co-Design for Actor Languages 72:19

Fig. 16. Strong scalability on 4–64 cores. (stw=stop-the-world.)

ORCA GC Comparison on µB’marks

Orca: GC and Type System Co-Design for Actor Languages 72:19

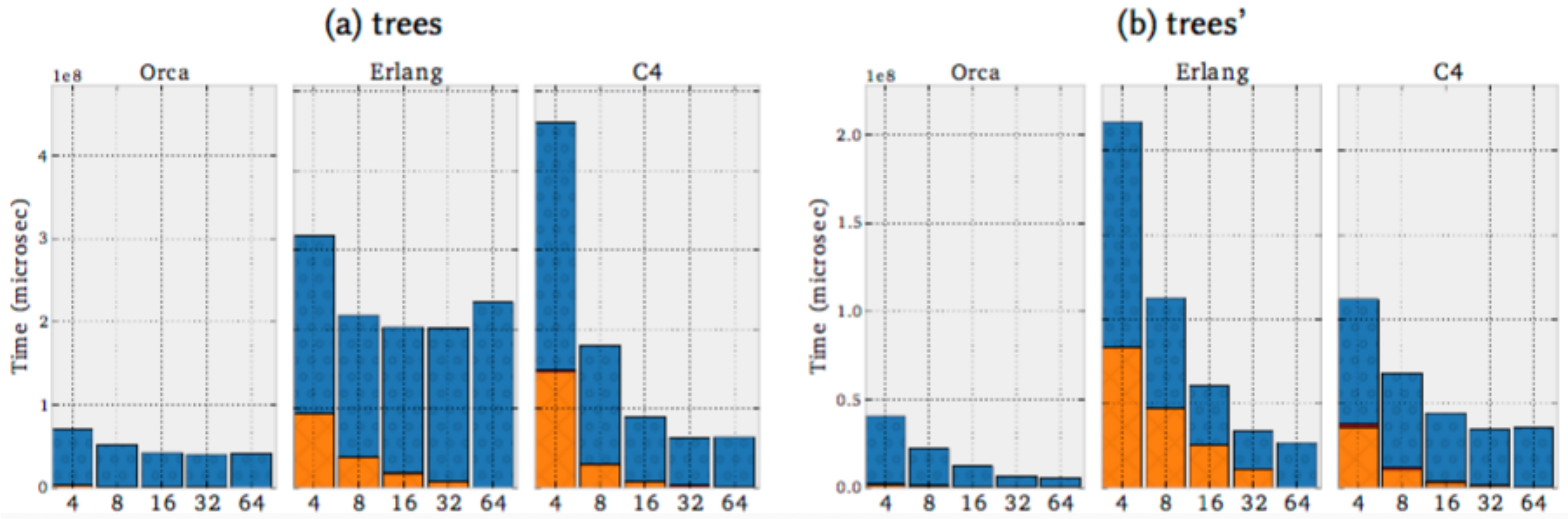
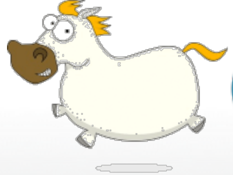


Fig. 16. Strong scalability on 4–64 cores. (stw=stop-the-world.)

Pony Is Not a Functional Language

- Pony is very imperative
- … but the type system provides lovely safety properties

Pony Has Lambdas & More

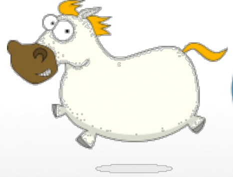


- lambdas / unnamed functions
- `map()` & friends, hooray
- persistent data structures in the standard library

Pony Is Object-Oriented

- … but not Java-style
- Not **everything** is an object
  - You control the class hierarchy
- Has both structural & nominal subtyping
  - Pony's `interface` = structural typing

Pony Has Generic Types

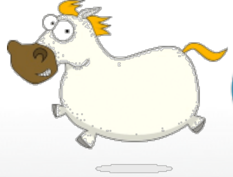


```
// map over a List[A] to
// create a List[B]

fun box map[B: B](
  f: {(this->A!): B^}[A, B] box)
: List[B] ref^
```

Pony Has Pattern Matching!

- `match` statement to match:
  - basic data types
  - sub-/super-types in class hierarchy
  - tuple element destructuring
- Function head matching is gone
  - … but will return again soon (I hope)

Pony Is Open Source

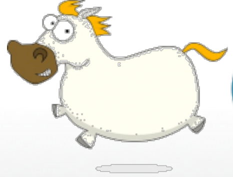


- BSD-style license
- https://github.com/ponylang/ponyc/
- Target CPUs
  - x86_64, ARM
- Target operating systems:
  - Linux, Windows, OS X
  - FreeBSD & DragonflyBSD (limited support)
- "Get Stuff Done" development model
  - Correctness > Performance > Simplicity > Consistency > Completeness

Pony Is Young

- The standard library is small
- The open source community is small
- Ecosystem of Pony language libraries & apps is small

Pony's FFI to C/C++ ABI

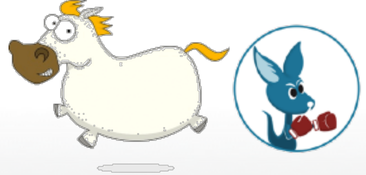


- Easily interface to C & C++ ABI functions
- Runtime's requirements for memory & threads are modest
- Many Pony primitive data types map directly to target CPU
  - `I8, I16, I32, I64, I128`
  - `U8, U16, U32, U64, U128`
  - `Array[U8]` for contiguous unstructured bytes

Pony's Reference Capabilities

- Strong, static type checker is the price to pay for safety
- It’s a big mind shift to adjust to both:
  - Mutable data (even if it is safe!)
  - Pony’s type system (based on affine types)
- The end advantages:
  - Zero runtime cost for safety
  - Very quick GC

Get Involved!



- Web: http://ponylang.org
- GitHub: https://github.com/ponylang/ponyc/
- Twitter: `@ponylang`
- Freenode IRC: `#ponylang`
- Mailing list info: https://pony.groups.io/g/user
- Pester me about Erlang, Pony, and/or Wallarc
  - Anytime here at the conference
  - `@slfritchie` on Twitter
  - `slfritchie@` on gmail.com