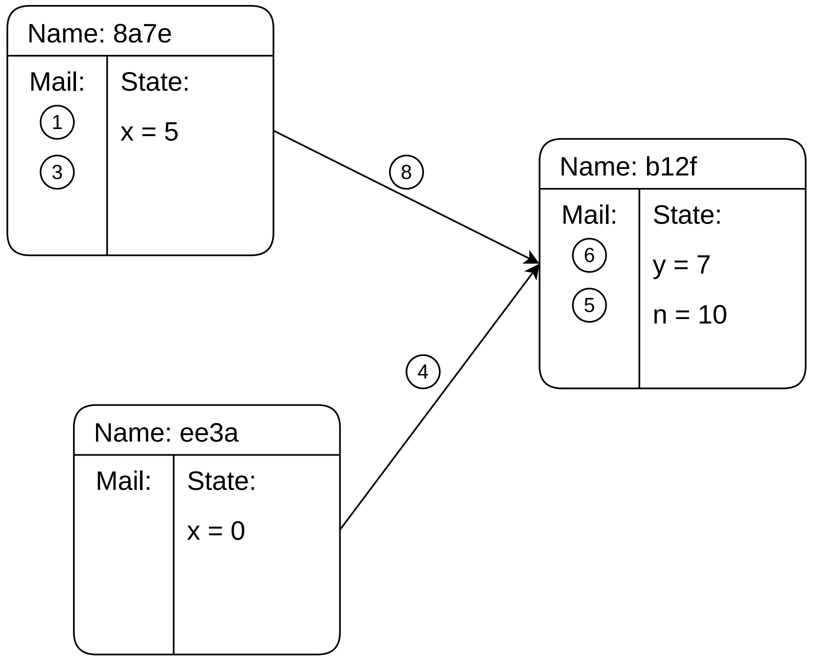
Actors

Actors Today

An actor has:

- a unique name
- a local state
- an unbounded mailbox
- a description of its behavior



The ACTOR Formalism

> This paper proposes a modular ACTOR architecture and definitional method for artificial intelligence that is conceptually based on a single kind of object: actors [or, if you will, virtual processors, activation frames, or streams].
> […]
> The architecture will efficiently run the coming generation of PLANNER-like artificial intelligence languages including those requiring a high degree of parallelism.
> […]
> The architecture is general with respect to control structure and does not have or need goto, interrupt, or semaphore primitives.

> Intuitively, an ACTOR is an active agent which plays a role on cue according to a script.
> […]
> Data structures, functions, semaphores, monitors, ports, descriptions, Quillian nets, logical formulae, numbers, identifiers, demons, processes, contexts, and data bases can all be shown to be special cases of actors.

Carl Hewitt, Peter Bishop, and Richard Steiger. 1973. A universal modular ACTOR formalism for artificial intelligence.

Patterns of Passing Messages

> In this paper we present an approach to modelling intelligence in terms of a society of communicating knowledge-based problem-solving experts.

> At a more superficial and imprecise level, each actor may be thought of as having two aspects which together realize the behavior which it manifests:
>
> the ACTION it should take when it is sent a message;
>
> its ACQUAINTANCES which is the finite collection of actors that it directly KNOWS ABOUT.

Carl Hewitt. 1977. Viewing control structures as patterns of passing messages.

Actors: a model of concurrent computation

> An actor may be described by specifying:
>
> - its mail address, to which there corresponds a sufficiently large mail queue; and,
> - its behavior, which is a function of the communication accepted.

> Actors are computational agents which map each incoming communication to a 3-tuple consisting of:
>
> 1. a finite set of communications sent to other actors;
> 2. a new behavior (which will govern the response to the next communication processed); and,
> 3. a finite set of new actors created

Gul Agha. 1986. Actors: a model of concurrent computation in distributed systems.

When to use them

- Distributed systems
- Servers and services
- Telecom and signalling systems
- Chat and messaging systems
- Event-driven microservices
- Online gaming backends

Elixir

https://elixir-lang.org

```
"Elixir" |> String.graphemes() |> Enum.frequencies()
```

Designed by José Valim, first appeared 2012

https://www.erlang.org

```
fact(0) -> 1;
fact(N) -> N * fact(N-1).

example:fact(10).
```

Based on Erlang, designed by Joe Armstrong, started 1986, open-sourced 1998

demo/basics.exs

demo/filesystem.exs

Actors in Erlang/Elixir

> Two processes operating on the same machine must be as independent as if they ran on physically separated machines.
>
> [...]
>
> 1. Processes have "share nothing" semantics. This is obvious since they are imagined to run on physically separated machines.
> 2. Message passing is the only way to pass data between processes. [...]
> 3. Isolation implies that message passing is asynchronous. [...]
> 4. Since nothing is shared, everything necessary to perform a distributed computation must be copied. [...]

Joe Armstrong. 2003. Making reliable distributed systems in the presence of software errors.

demo/processes.exs

Names of Actors

> We require that the names of processes are unforgeable. This means that it should be impossible to guess the name of a process, and thereby interact with that process. We will assume that processes know their own names, and that processes which create other processes know the names of the processes which they have created.
> [...]
> In many primitive religions it was believed that humans had powers over spirits if they could command them by their real names. Knowing the real name of a spirit gave you power over the spirit, and using this name you could command the spirit to do various things for you

Joe Armstrong. 2003. Making reliable distributed systems in the presence of software errors.

PIDs in Elixir

https://hexdocs.pm/elixir/Kernel.html#self/0

```
self()
```

> Returns the PID (process identifier) of the calling process.

https://hexdocs.pm/elixir/Kernel.html#spawn/1

```
spawn(fun)
```

> Spawns the given function and returns its PID.

demo/names.exs

Message Passing

> Message passing obeys the following rules:
>
> 1. Message passing is assumed to be atomic which means that a message is either delivered in its entirety or not at all.
> 2. Message passing between a pair of processes is assumed to be ordered meaning that if a sequence of messages is sent and received between any pair of processes then the messages will be received in the same order they were sent.
> 3. Messages should not contain pointers to data structures contained within processes — they should only contain constants and/or Pids.

> We say that such message passing has *send and pray semantics*. We *send* the message and *pray* that it arrives.

Joe Armstrong. 2003. Making reliable distributed systems in the presence of software errors.

Message Passing in Elixir

https://hexdocs.pm/elixir/Kernel.html#send/2

```
send(dest, message)
```

> Sends a message to the given dest and returns the message.

https://hexdocs.pm/elixir/Kernel.SpecialForms.html#receive/1

```
receive(args)
```

> Checks if there is a message matching any of the given clauses in the current process mailbox.

demo/messages.exs

demo/order.exs

Message Buffers are Unbounded

> In a purely physical context, the finiteness of the universe suggests that a communication sent ought to be delivered.
> [...]
> There are, realistically, no unbounded buffers in the physically realizable universe. This is similar to the fact that there are no unbounded stacks in the universe, and certainly not in our processors, and yet we parse recursive control structures in algolic languages as though there were an infinite stack.

> The alternate to assuming unbounded space is that we ave to assume some specific finite limit; but each finite mit leads to a different behavior. There is, however, no general limit on buffers: the size of any real buffer will be specific to ay particular implementation and its limitations.

Gul Agha. 1986. Actors: a model of concurrent computation in distributed systems.

demo/overflow.exs

Changing State

We tail-call the actor with another argument.

```
def loop(count) do
  receive do
    :increment ->
      loop(count + 1)
  end
end
```

demo/increment.exs

demo/state.exs

Reply-to Addresses

> Often the envelope of a messenger is a REQUEST which In addition to a request message contains an actor c to which a reply to the request should be sent. Such an envelope is packaged as follows:
>
> (request: the-message (reply-to: c))
>
> The ACTOR c Is closely related to the continuation FUNCTIONS used by Morris, Wadsworth, Reynolds,and Strachey.

> An ordinary functional call to a function f with arguments arg_1, ..., through arg_k is implemented in PLASMA by passing to f a request envelope with a message consisting of the tuple [arg_1, ..., arg_k] of arguments and a continuation actor to which the value of f should be sent.

Carl Hewitt. 1977. Viewing control structures as patterns of passing messages.

demo/reply.exs

Correlation Tokens

https://hexdocs.pm/elixir/Kernel.html#make_ref/0

```
make_ref()
```

Returns an almost unique reference.

demo/correlation.exs

demo/chat_client.exs

demo/chat_server.exs

Let it crash

> The Erlang philosophy for handling errors can be expressed in a number of slogans:
>
> - Let some other process do the error recovery.
> - If you can’t do what you want to do, die.
> - Let it crash.
> - Do not program defensively.

Joe Armstrong. 2003. Making reliable distributed systems in the presence of software errors.

Supervisors in Elixir

https://hexdocs.pm/elixir/Kernel.html#spawn_link/1

```
spawn_link(fun)
```

> Spawns the given function, links it to the current process, and returns its PID.

https://hexdocs.pm/elixir/Process.html#flag/2

```
flag(:trap_exit, boolean())
```

> Sets the given flag to value for the calling process.

https://hexdocs.pm/elixir/Process.html#exit/2

```
exit(pid, reason)
```

> The following behavior applies if reason is any term except `:normal` or `:kill`:
>
> 1. If pid is not trapping exits, pid will exit with the given reason.
> 2. If pid is trapping exits, the exit signal is transformed into a message `{:EXIT, from, reason}` and delivered to the message queue of pid.

demo/supervisor.exs

demo/division.exs

Deadlocks

> Deadlock, in a strict syntactic sense, can not exist in an actor system. In a higher level semantic sense of the term, deadlock can occur in a system of actors.

Gul Agha. 1986. Actors: a model of concurrent computation in distributed systems.

Dining Philosophers:

- Forks are actors
- Philosophers are actors

demo/dining.exs

demo/timeout.exs

Location Transparency

Generally, we want to refer to a resource by a high-level name, independent of its low-level location.

Examples:

- Phone contacts
- Support hotline
- Virtual memory
- File names
- Domain names

Even more important in distributed systems.

Location Transparency in Elixir

https://hexdocs.pm/elixir/Process.html#register/2

```
register(pid_or_port, name)
```

Registers the given `pid_or_port` under the given name on the local node.

https://hexdocs.pm/elixir/Process.html#whereis/1

```
whereis(name)
```

Returns the PID or port identifier registered under `name` or `nil` if the name is not registered.

demo/registry.exs

Nodes

```
iex --sname node1
```

https://hexdocs.pm/elixir/Kernel.html#node/0

```
node()
```

> Returns an atom representing the name of the local node.

https://hexdocs.pm/elixir/Node.html#connect/1

```
Node.connect(node)
```

> Establishes a connection to node.

demo/distributed.exs

Global Names

https://www.erlang.org/doc/apps/kernel/global.html#register_name/2

```
:global.register_name(Name, Pid)
```

> Globally associates name Name with a pid, that is, globally notifies all nodes of a new global name in a network of Erlang nodes.

https://www.erlang.org/doc/apps/kernel/global.html#whereis_name/1

```
:global.whereis_name(Name)
```

> Returns the pid with the globally registered name Name. Returns undefined if the name is not globally registered.

demo/global.exs

Fairness Guarantee in Elixir

The abstract machine uses reduction-based preemptive scheduling.

Each function call, message send, etc. costs 1 reduction.

The scheduler preempts a process after 2000 steps.

No starvation of processes is possible.

demo/fairness.exs

Summary and Outlook

Actors provide a natural structure for concurrent applications.

Next week: Model View Update