Resurrecting Actors:

New Applications of an Old Paradigm in Engineering and Science

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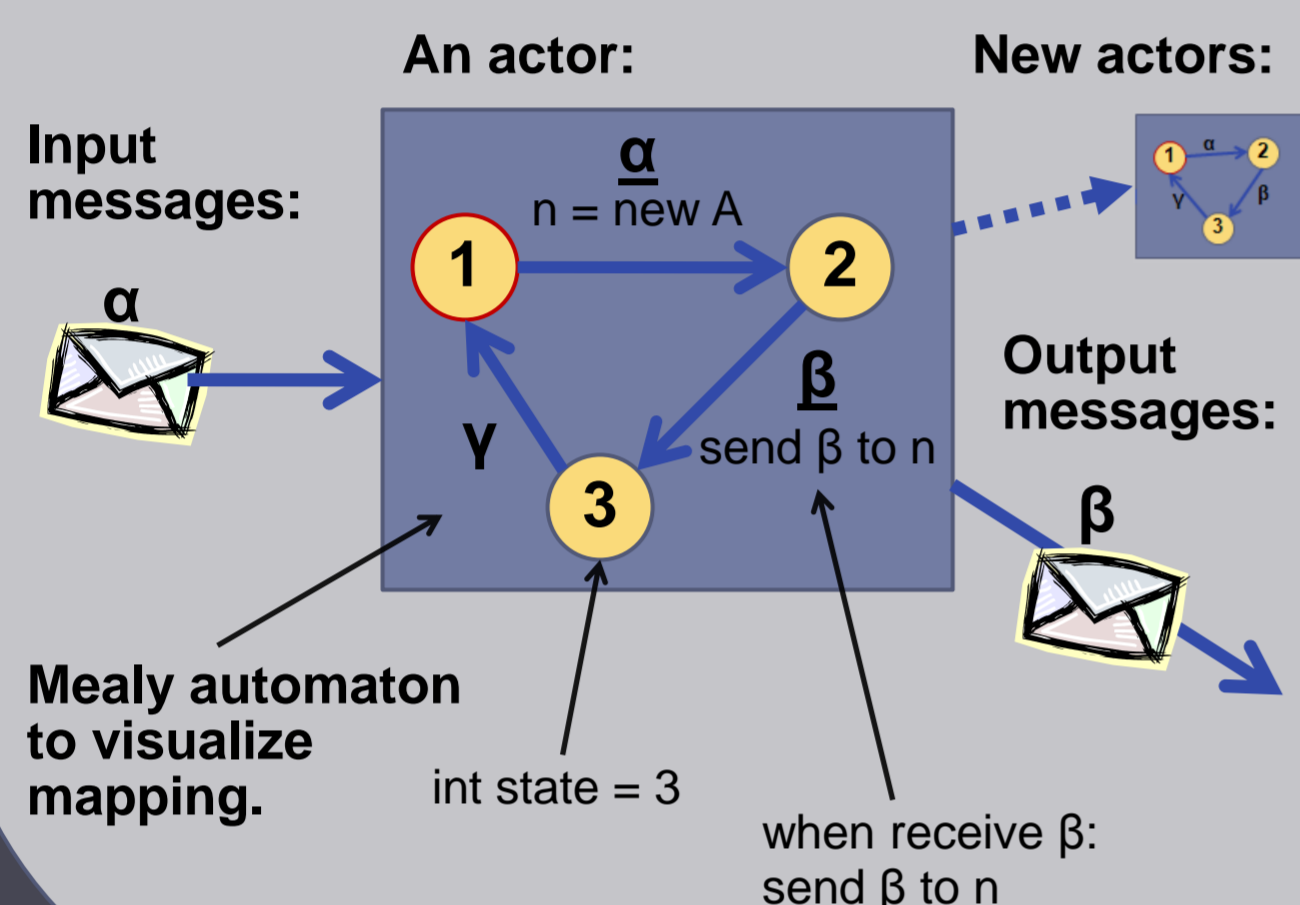
The Actor Model

- **Model of concurrent computation**
- Proposed in 1977 by C. Hewitt [1].
- Actor = a mapping between an input communication and a triple:
  - New state/behaviour,
  - Communications to send, and
  - New actors to create
- Communicate only via message passing
- Isolated (no shared state)
- Implicitly concurrent, with **no locks and no shared memory.**
- More flexible than shared memory model
- **Easily distributed and migrated.**
- Was **stillborn** as a niche AI interest due to:
  - Functional programming bias
  - Lack of highly distributed architectures
  - Inefficiency of message passing

- Now being **revived** in various fields due to:
  - Need to program new complex distributed architectures (multi-core, WSNs, clouds).
  - Usefulness of abstraction in automated code generation & optimizations.
  - Use of familiar imperative & OO syntaxes

```java
class A: Actor { // Java
  A nghbor;
  int state = 1;
  receive(Msg m) {
    switch (state) {
    case 1: if (m == Msg.ALPHA) {
        state = 2;
        nghbor = new A();} break;
    case 2: if (m == Msg.BETA) {
        state = 3;
        nghbor.send(Msg.BETA);} break;
    case 3: if (m == Msg.GAMMA)
        state = 1; break;
    }}
}
```

```lisp
(defun ActorA (state neighbor) ; Lisp
  (lambda (msg)
    (case state
      (1 (if (= msg 'alpha)
          (ActorA 2 (ActorA 1 nil))
          (ActorA state neighbor)))
      (2 (if (= msg 'beta)
          (ActorA 3 (neighbor 'beta))))
          (ActorA state neighbor)))
      (3 (if (= msg 'gamma)
          (ActorA 1 neighbor)
          (ActorA state neighbor))))))
```


An actor:

Input messages: α

α
n = new A
γ
1 → 2
3
β
send β to n

New actors:

Output messages: β

Mealy automaton to visualize mapping.

int state = 3

when receive β: send β to n

Massively Distributed Computation

- **"Internet Operating System"**: Middleware for internet scale distributed computing with SALSA actors (and MPI) [5].
- Implements: Adaptive decentralized load balancing by profiling runtime actor topology (ARS).

Non-optimal

Load balanced

(mps = messages per second)
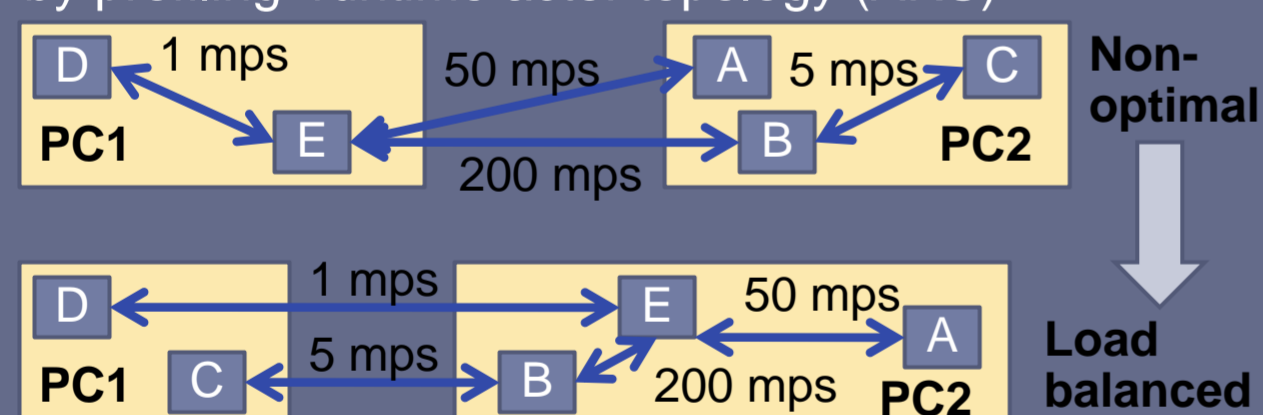
- ARS gave 10x performance increase over round robin on sparse topology benchmark.

Wireless Sensor Networks

- **"ActorNet"**: Mobile agent platform for WSNs via a custom Scheme interpreter [3].
- Provides: Actor migration, Virtual memory, Garbage collection, and Multitasking for Mica2.
- Enables: program portability, remote code deployment, & reconfiguration to conserve energy.
- Used as the basis of the uQueries domain specific language.

Meta-actors representing a query deploy mobile actors

Internet
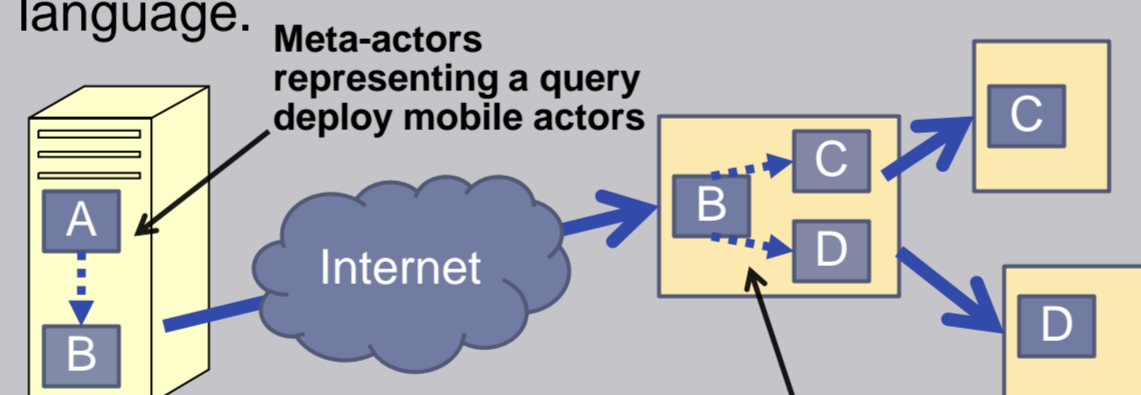
Remotely reprogramming a WSN using actorNet.

Duplicating and migrating actor continuations, across the WSN

Signal Processing

- **"CAL"**: Domain specific actor language for signal processing algorithms [4].
- Automatic code generation of C and VHDL via recent **CAL2C** and **CAL2HDL** generators [6].
- Very concise, more flexible, architecture independent implementation => portable.
- Visual & hierarchical design via Ptolemy II [7].

```
actor sum[T] (T init) T A ==> T B:
  T sum := init;
  action [a] ==> [sum] do
    sum := sum + a;
  endaction
endactor      [8]
```
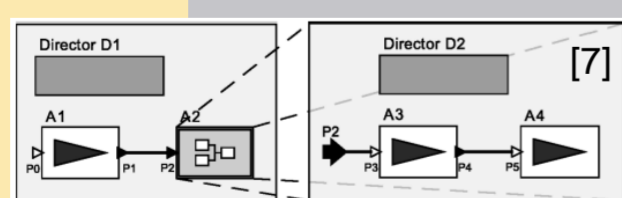

- MPEG4 Decoder: 4000lines CAL vs 15000 VHDL, **1.6x faster** performance & 4x faster development than handwritten VHDL.
- Used by ISO for new MPEG "RCV" codec.

Conclusions

- **Kilim** demonstrates:
  - Actor continuation passing allows **fast task switching**
  - **Linear type systems** can enable resource sharing & **fast message passing**.
- **IOS & ActorNet** exploit:
  - Actor migration to provide adaptive **mobile agent based programming.**
- **CAL** shows actor-oriented programming can be
  - very concise, logical hierarchical structure, intuitive concurrency, and **allows efficient multiplatform code generation.**
- As architectures are becoming more distributed and more abstraction is required, the predicted benefits of the Actor model are beginning to be realized over 30 years after its conception [9].

Concurrency: Actors & Linear Types

- **"Kilim"**: Lightweight Java actors [2]
- Implemented via a byte code weaver
- Offers:
  - 1000s of fast lightweight threads.
  - Efficient cooperative scheduling.
  - Actor memory isolation and efficient "zero-copy" message passing, via a **statically enforced linear type system**
- **Overcomes inefficiency of message passing via linear ownership passing of messages:**

```java
import kilim.*;

class HtmlMsg implements Message {
  public String html; public HttpRequest req; }
class HttpRequest implements Message {
  public Mailbox<HtmlMsg> replyTo;
  public String url; public String[] cookies; }
class DatabaseConnection implements Message {
  public Object jdbcConnection; }

class RequestQueue extends Mailbox<HttpRequest> {}
class DBConnectionPool extends Mailbox<DatabaseConnection> {}

class HttpRequestHandler extends Actor {

  RequestQueue in; DBConnectionPool pool;
  Mailbox<HtmlMsg> cartmb = new Mailbox<HtmlMsg>(),
    searchmb = new Mailbox<HtmlMsg>();
  ShoppingCartControl cartControl = ... ;
  SearchResultsControl searchControl = ... ;

  @pausable
  public void execute() {
    for(;;) {
      HttpRequest req = in.get();
      HtmlMsg reply = new HtmlMsg();
      handle(req, reply);
      sendReply(req, reply);
    }}

  @pausable
  void handle(@safe HttpRequest req, @cuttable HtmlMsg reply) {
    HttpRequest r = req.clone(); r.replyto = cartmb;
    cartControl.put(r);
    r = req.clone(); r.replyto = searchmb;
    searchControl.put(r);
    reply.html = "<html>"+cartmb.get() + searchmb.get() + "</html>";
  }

  @pausable
  void sendReply(@free HttpRequest req, @free HtmlMsg reply) {
    reply.req = req;
    reply.req.replyTo.put(reply);
  }

  @pausable
  private Results query(@safe DatabaseConnection con,
    @safe String sql) {...}
}

class ShoppingCartControl extends HttpRequestHandler {
  @pausable
  void handle(@safe HttpRequest req, @cuttable HtmlMsg reply){
    DatabaseConnection con = pool.get();
    Results r = query(con, "select * from carts where ...");
    reply.html = "<h2>Cart</h2><table>"+r.print()+"</table>";
    pool.put(con);
  }
}

class SearchResultsControl extends HttpRequestHandler {
  @pausable
  void handle(@safe HttpRequest req, @cuttable HtmlMsg reply) {
    DatabaseConnection con = pool.get();
    Results r = query(con, "select * from products where ...");
    reply.html = "<h2>Search results</h2><div>" + r.print() + "</div>";
    pool.put(con);
  }
}
```
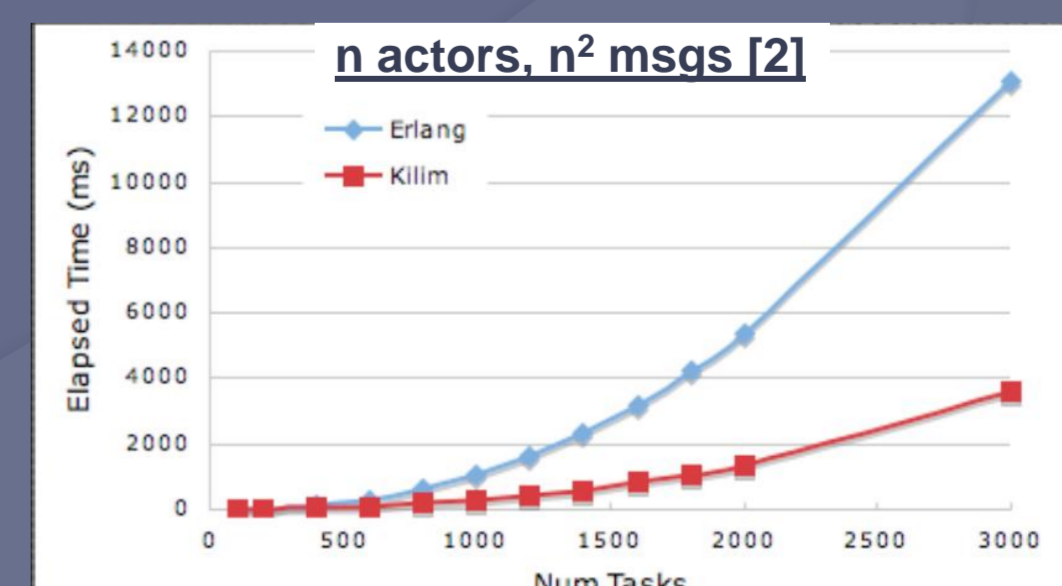
Messages are public tree structures

Method may suspend
Actor entry point
May be structurally modified but not sent
May only be read
- r is free
- r is invalid
- r is free
- r is invalid
May be sent / destructively read
- reply is free, req is cuttable
- reply is invalid, req is invalid
Send message / transfer ownership
Receive message / get ownership
- con is free
- con is invalid

- **Example: renders 2 parts of webpage in parallel**
  - When blocking on DB another part of page/request can be handled via fast task switching.
  - Database connections shared by a queue and linear ownership passing (no locks).
- **Very fast: 4x faster than Erlang, 100x Java threads!**

n actors, n² msgs [2]

Elapsed Time (ms) vs Num Tasks

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[5] K. E. Maghraoui, T. J. Desell, B. K. Szymanski, and C. A. Varela, "The internet operating system: Middleware for adaptive distributed computing," in International Journal of High Performance Computing Applications (IJHPCA), Special Issue on Scheduling Techniques for Large-Scale Distributed Platforms, 2006.

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