Programming Concurrency

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What is concurrency?

Demo

Language-based approach

Programming

- Programming Languages Design
  - Domain-specific Languages (DSL)
- New abstractions
  - Expressivity
  - Safety
  - Efficiency

Compilation

- Static analysis, Typing
- Efficient code generation

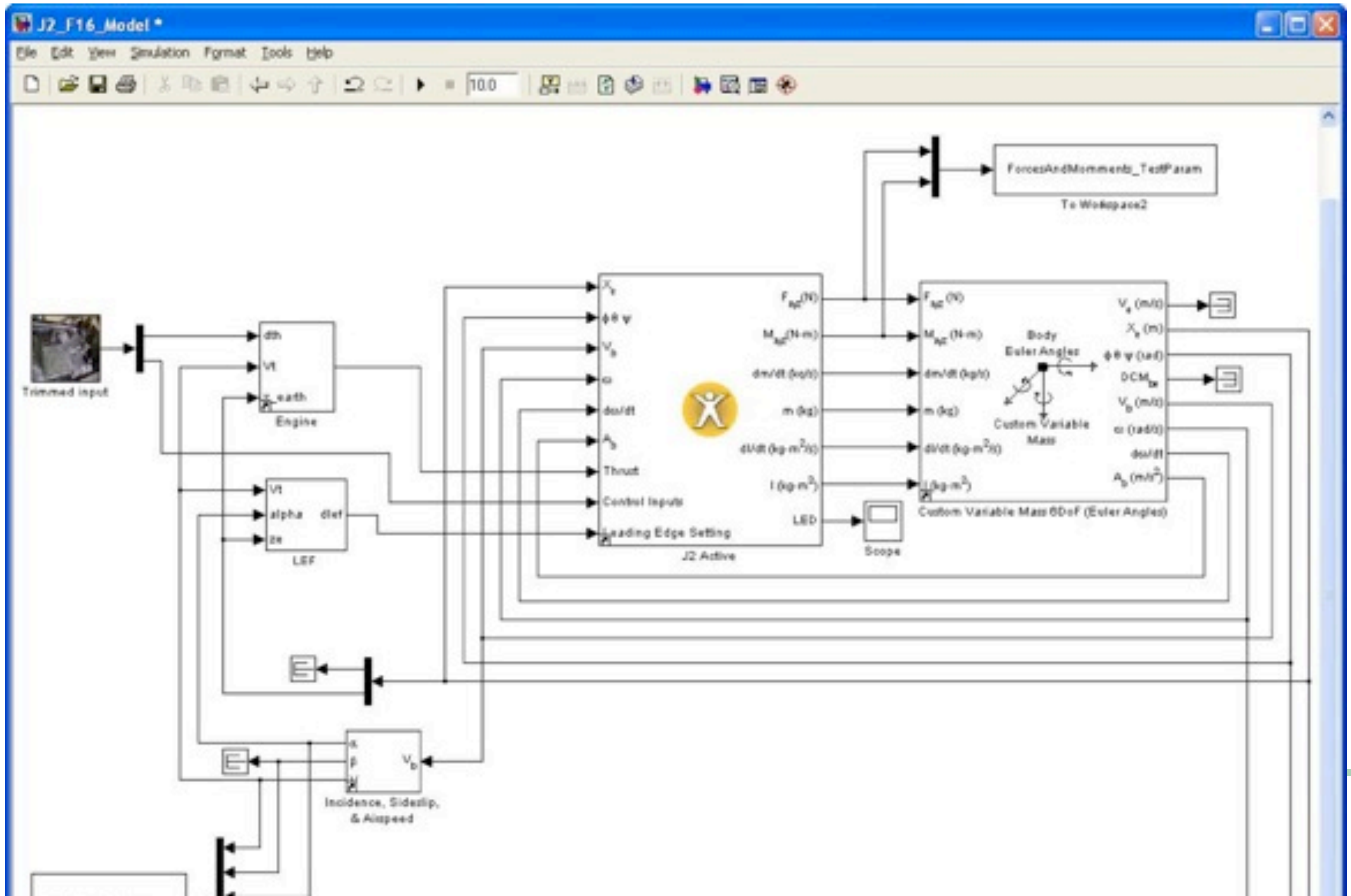
(Some) Concurrent Systems

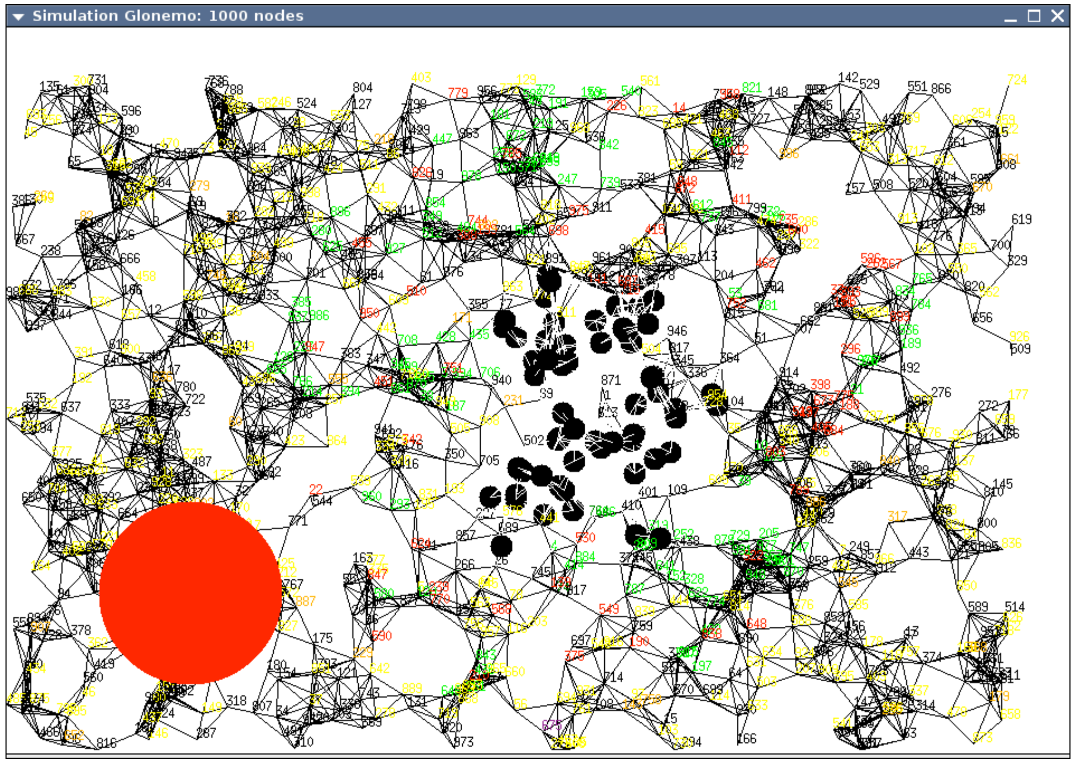
Embedded Systems

Simulation of embedded systems

Hybrid (ODE) (Simulink , Modelica)

Discrete





Concurrency ≠ Parallelism

Concurrency = Model

- Doing several things at the same time
- Does not require hardware parallelism

Parallelism = Implementation

- Multi-core
- Going faster
- Implementation

Contents

Contents

Synchronous languages

Domain-specific languages for embedded systems

- Created in the 80's in France
  - Lustre (Caspi & Halbwachs, Grenoble)
  - Signal (Benveniste & Le Guernic, Rennes)
  - Esterel (Berry & Gonthier, Sophia)

Principles

- Time
- Deterministic Concurrency
- Mathematical foundations (= Semantics)
  - Formal verification

Synchronous languages

Programming embedded sytems

- Reactive
- Real-time
- Critical

Interaction loop

- Read inputs (sensors)
- Compute
- Write outputs (actuators)

The synchronous hypothesis

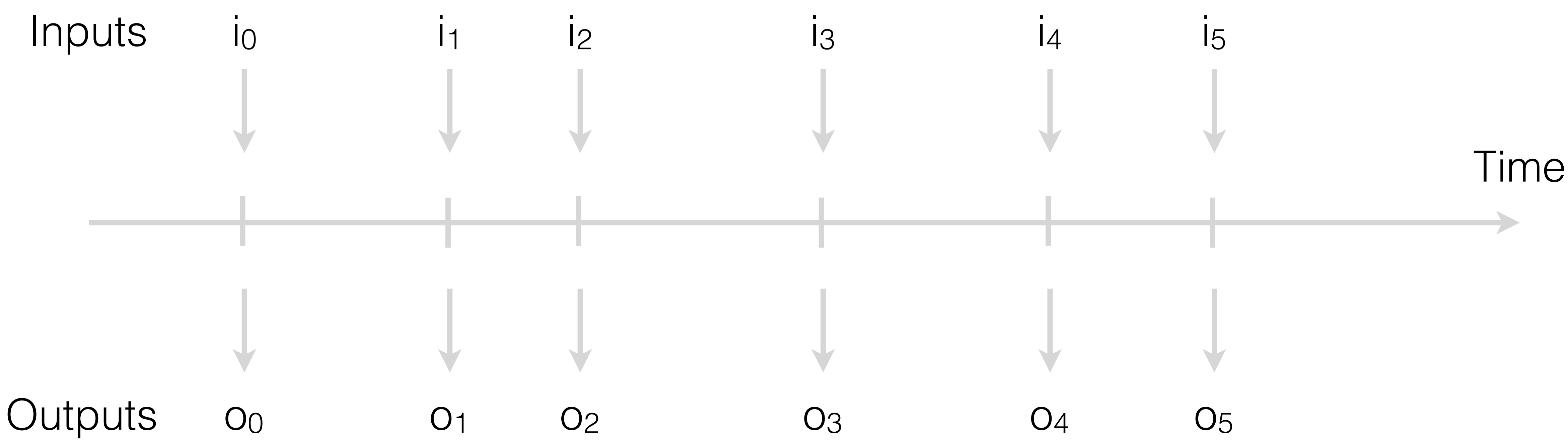
Time

- Discrete
- Logical
- Global

The synchronous hypothesis

Computation and communication are instantaneous

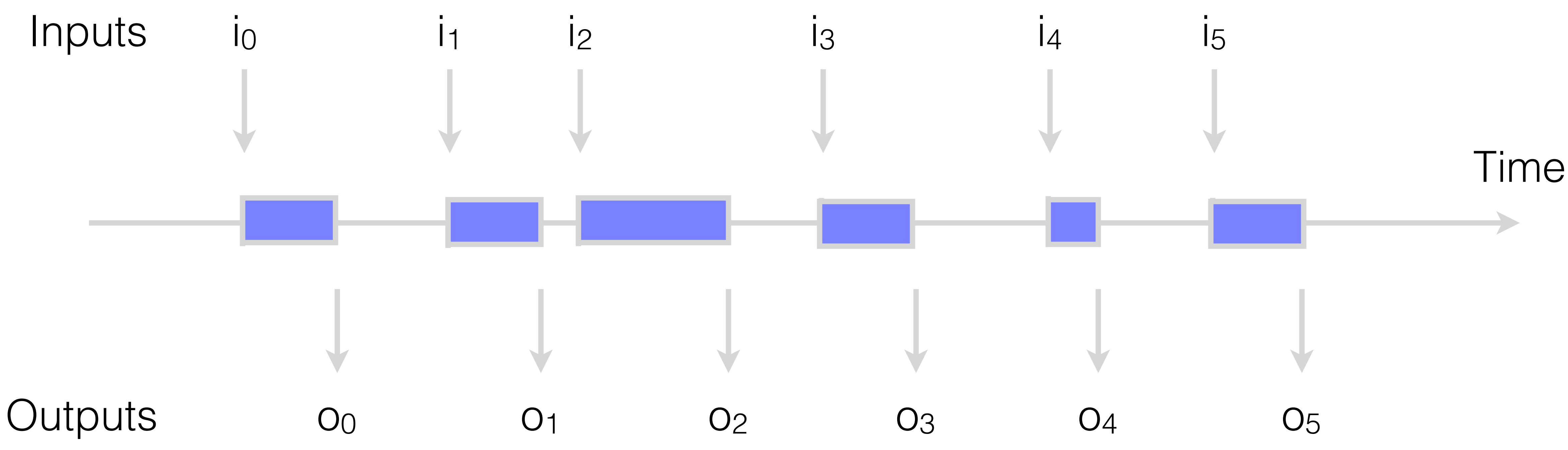
- Computer is infinitely fast



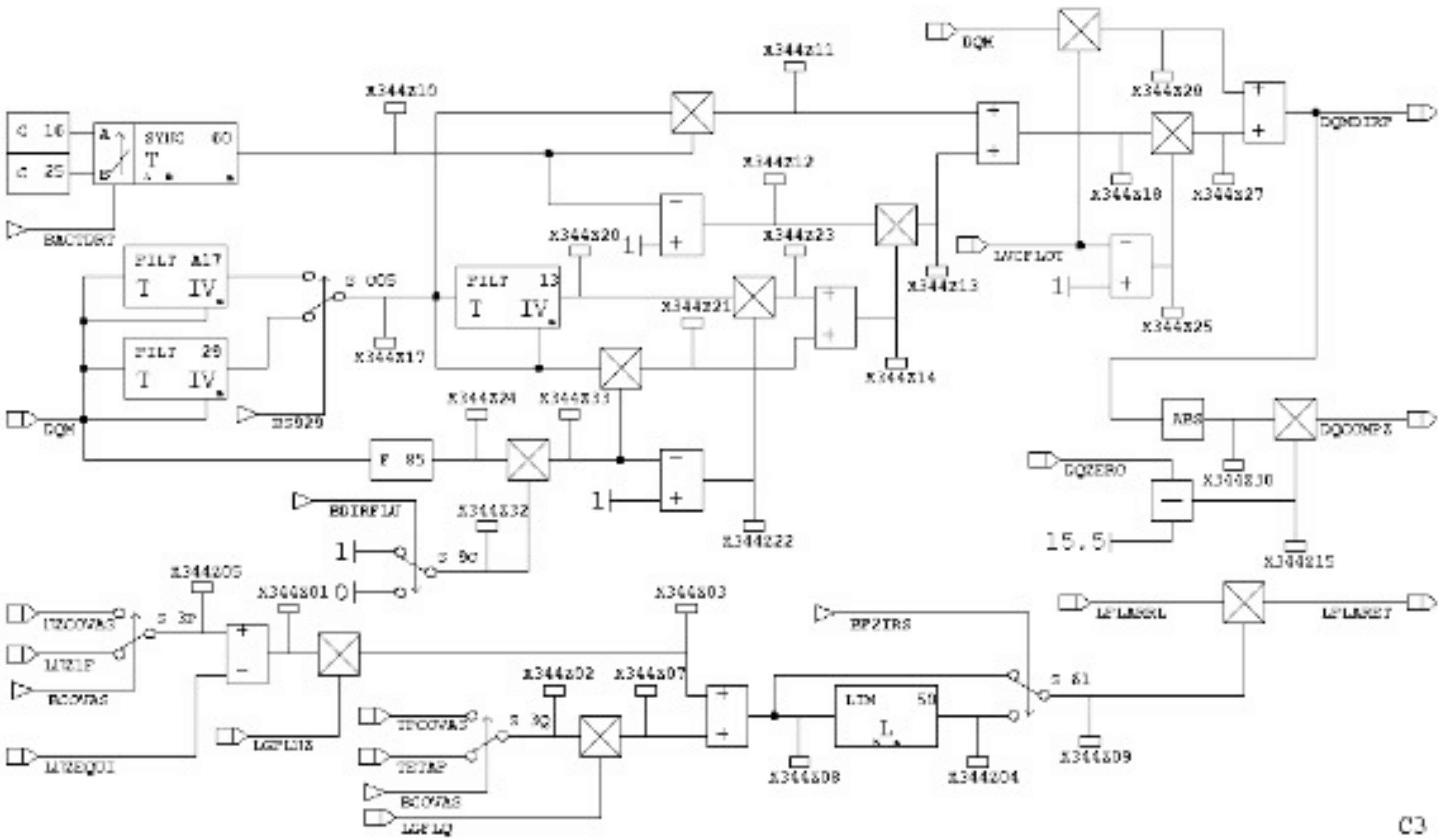
The synchronous hypothesis

Computation and communication are instantaneous

- Computer is infinitely fast
- Check if hypothesis holds



Computer assisted specification (Airbus, 80's)



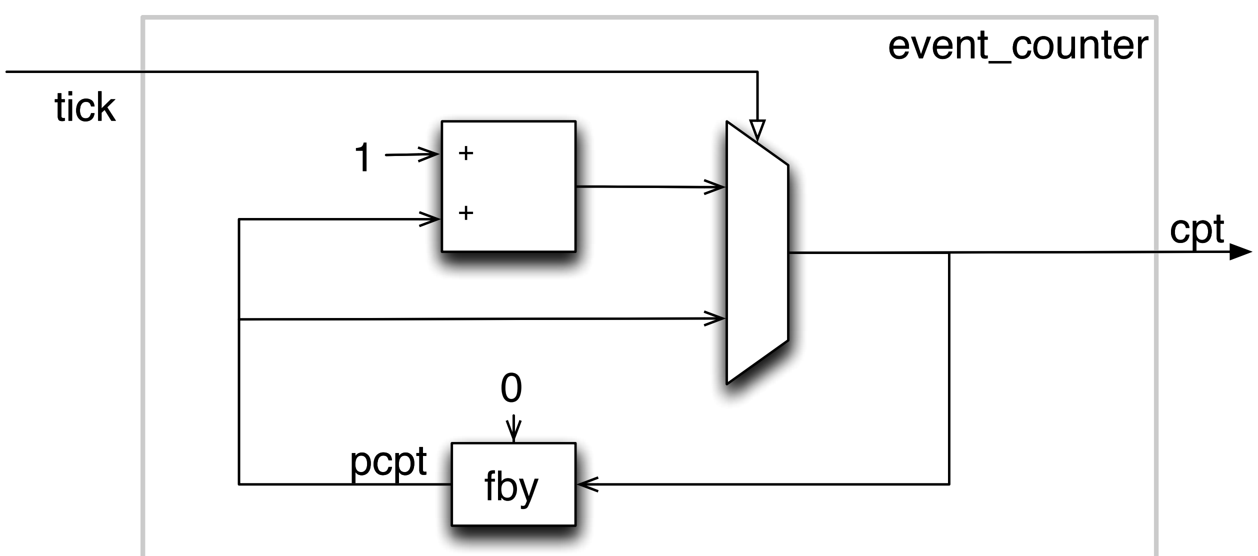
Lustre

Synchronous data-flow language

- Equations on flows (= inifinite sequence)

Example

- A counter



Lustre

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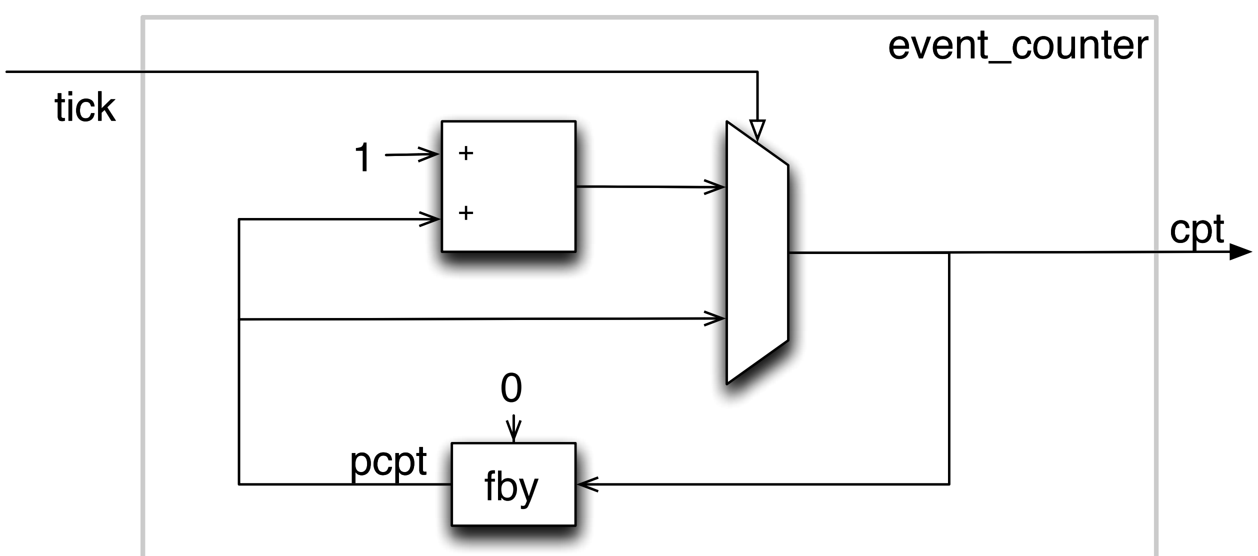


$$pcpt_0 = 0$$

$$pcpt_{i+1} = cpt_i$$

$$cpt_i = \begin{cases} pcpt_i + 1 & \text{if } tick_i \\ pcpt_i & \text{otherwise} \end{cases}$$

Lustre

Synchronous data-flow language

- Equations on flows (= inifinite sequence)

Example

- A counter

```
node event_counter
 (tick:bool) = (cpt:int)
var pcpt:int;
let
  pcpt = 0 fby cpt;
  cpt = if tick
        then pcpt + 1
        else pcpt;
tel
```

$$pcpt_0 = 0$$

$$pcpt_{i+1} = cpt_i$$

$$cpt_i = \begin{cases} pcpt_i + 1 & \text{if } tick_i \\ pcpt_i & \text{otherwise} \end{cases}$$

Lustre

Code generation

- Sequential code
- Efficient
- Bounded time (WCET) and memory

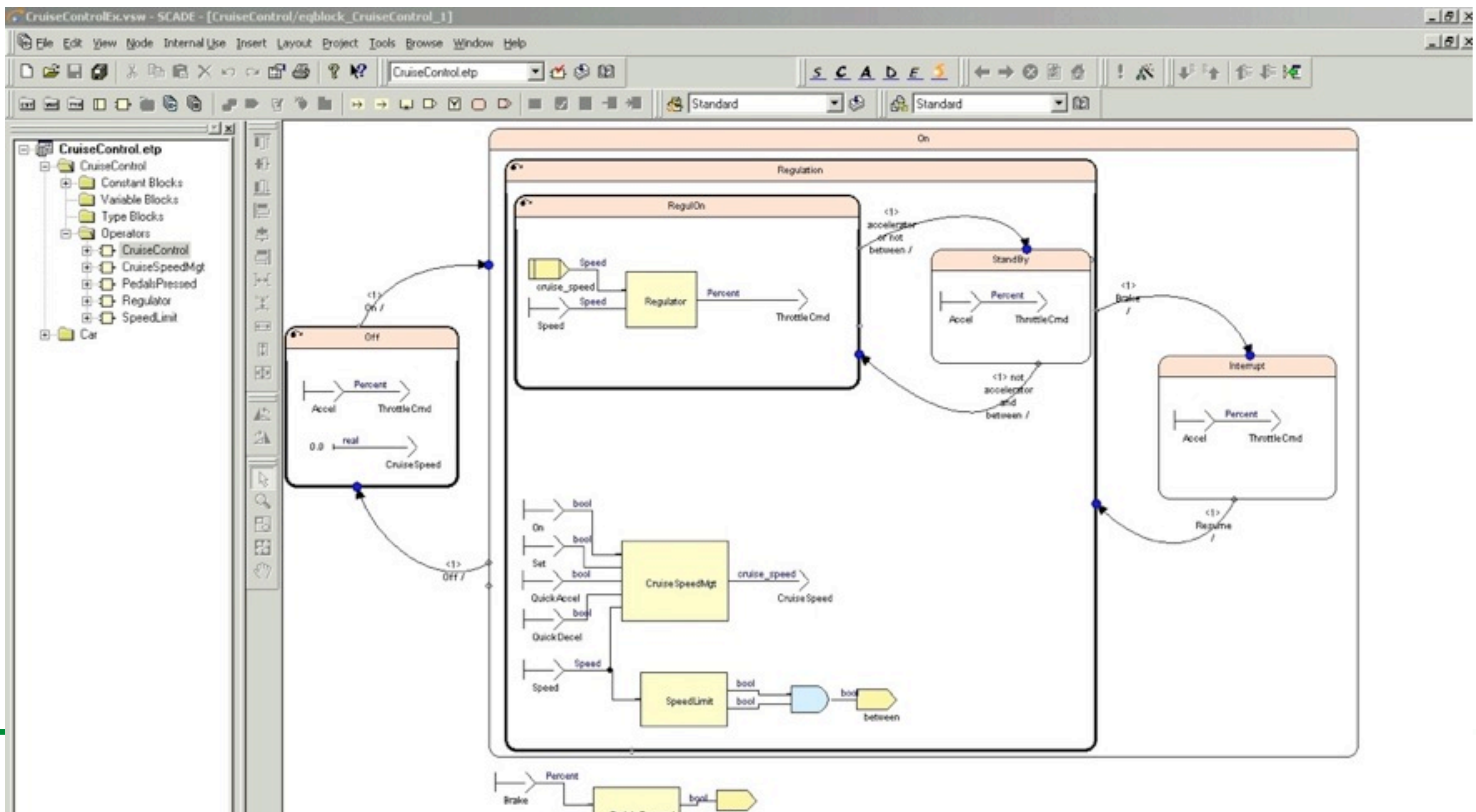
Formal verification

- Model-checking

SCADE

Safety-critical embedded systems

- Plane, trains, subways, nuclear plants
- Certified/Qualified (DO-178B, IEC 61508, etc.)



Contents

ReactiveML

Synchrony in a general-purpose language

- No real-time
- Dynamic creation

ReactiveML

- Functional language (ML, OCaml)
- Synchronous model of concurrency
  - Discrete logical time
  - Communication by broadcast

Application

- Discrete simulation

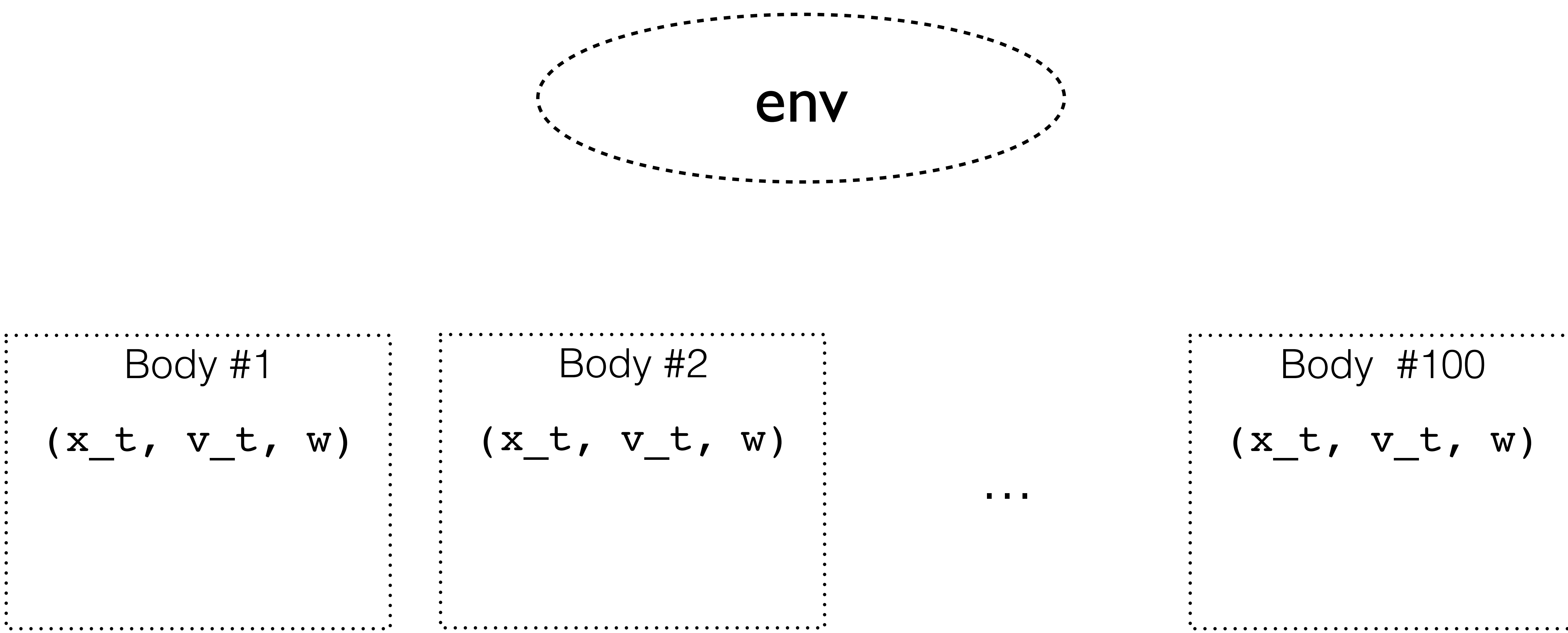
n-body problem

- Simulate the gravitational interactions of n bodies
- Numerical integration methods

$$m_i \vec{a}_i = \vec{f}_i = \sum_j \vec{F}_{i,j}$$

N-body in ReactiveML

- One process per body
- A global signal



N-body in ReactiveML

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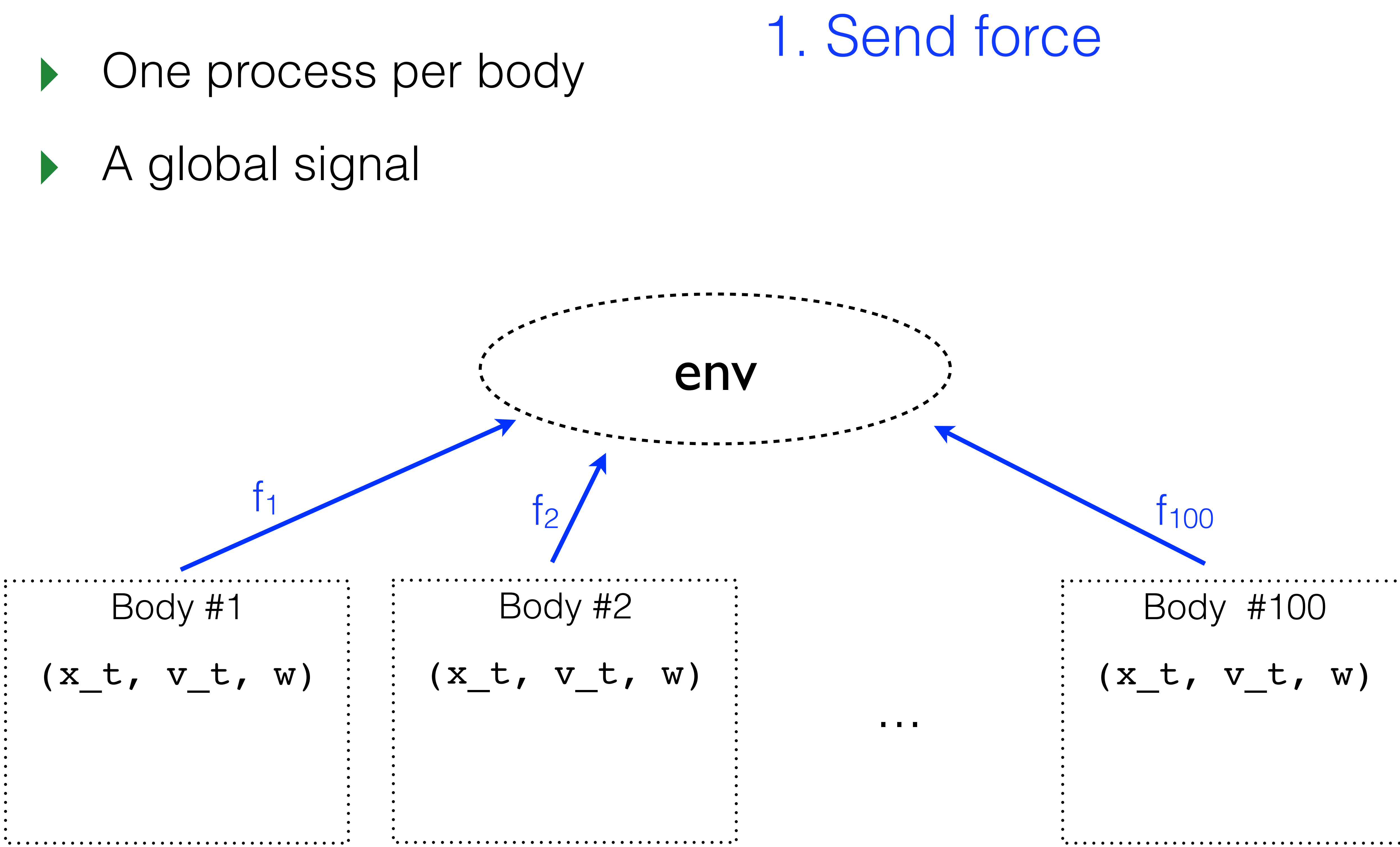
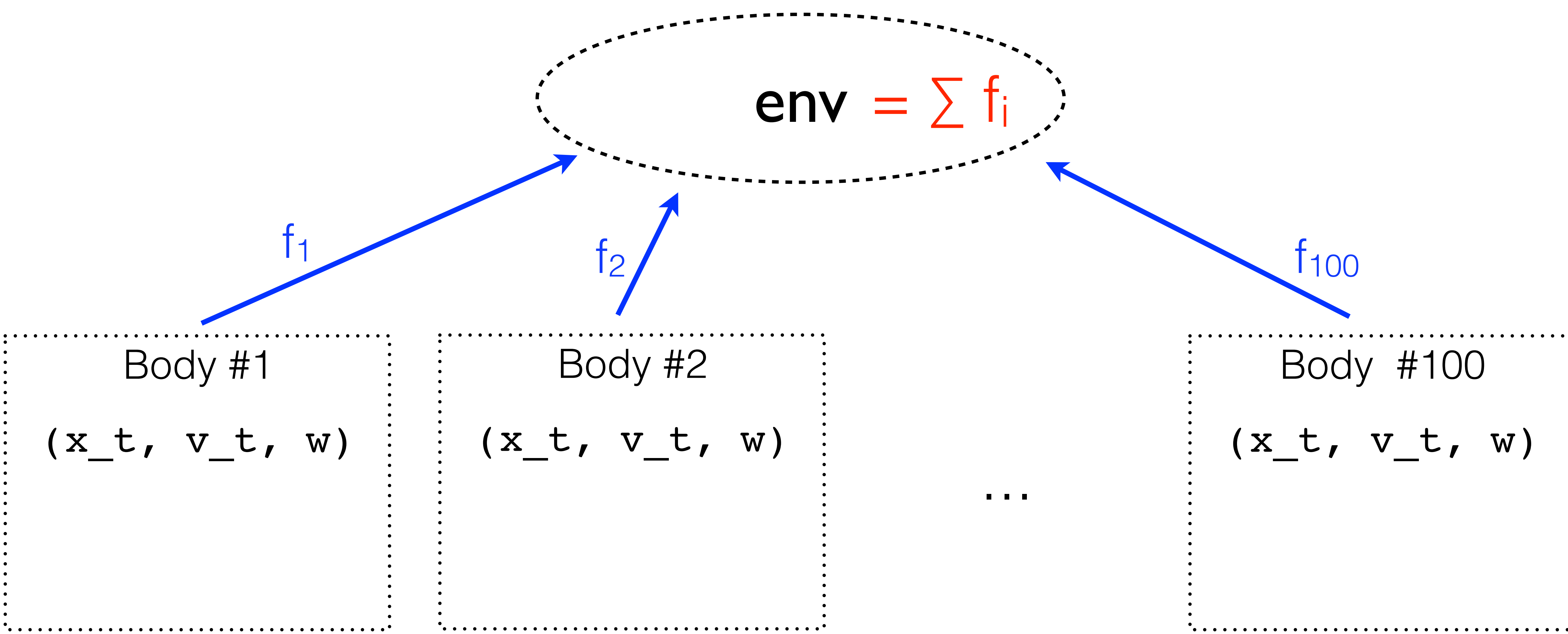


N-body in ReactiveML

- One process per body
- A global signal

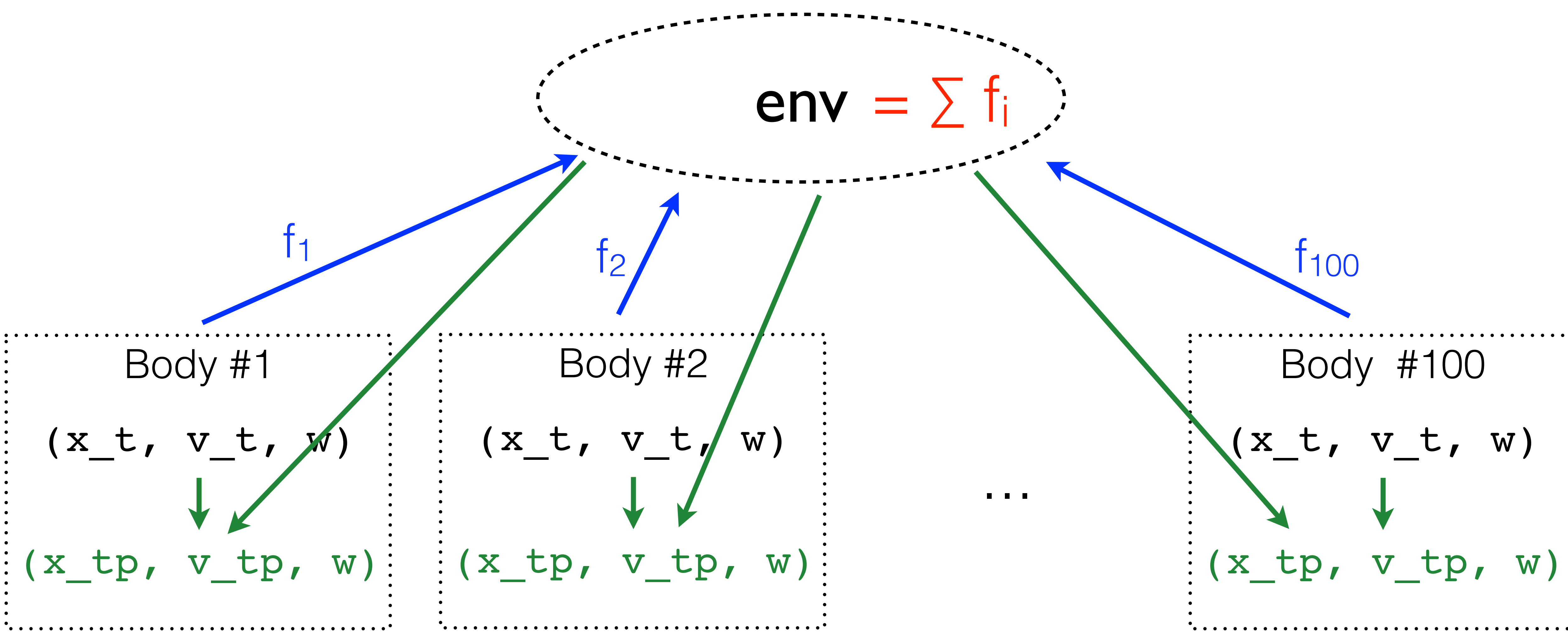
1. Send force
2. Collect forces



N-body in ReactiveML

- One process per body
- A global signal

1. Send force
2. Collect forces
3. Compute new position



N-body in ReactiveML

```
let dt = 0.01
signal env default (fun _ -> zero_vector)
           gather add_force

let rec process body (x_t, v_t, w) =
  emit env (force (x_t, w));
  await env(f) in
  (* euler semi-implicit method *)
  let v_tp = v_t ++. (dt **. (f x_t)) in
  let x_tp = x_t ++. (dt **. v_tp) in
  run body (x_tp, v_tp, w)

let process main =
  for i = 1 to 100 dopar
    run body (random_planet ())
  done
```

Contents

Motivation

Different time scales

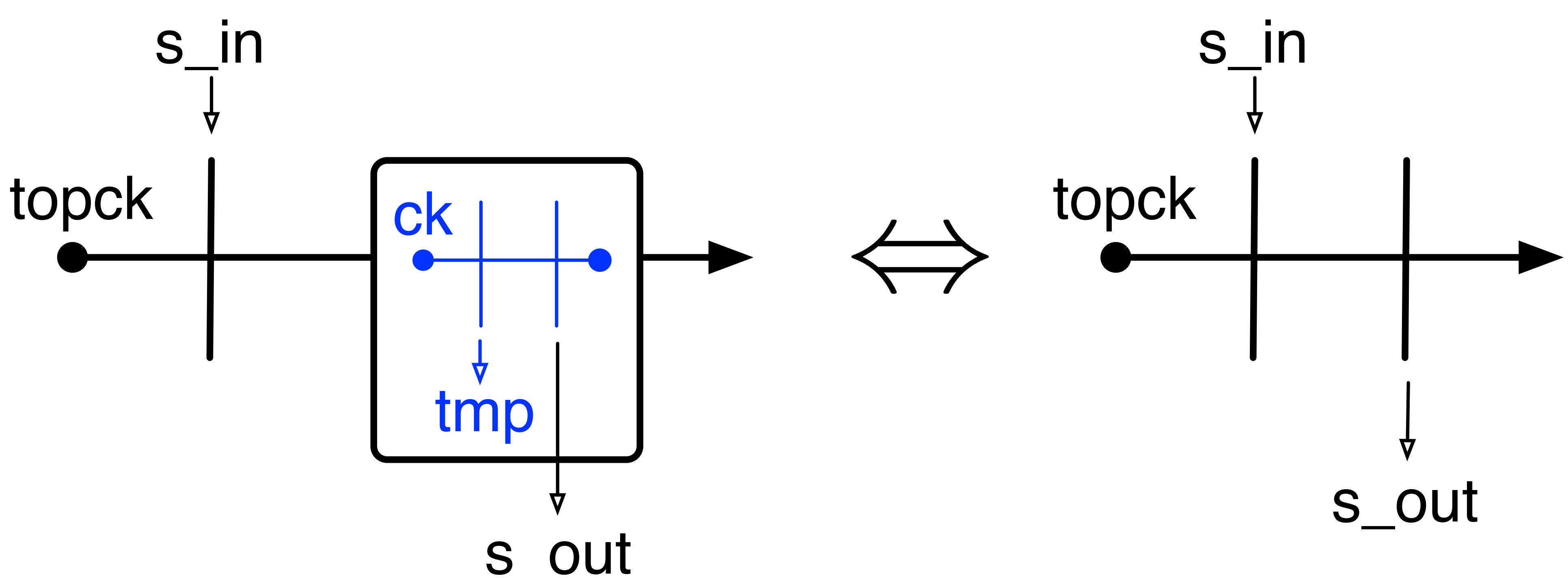
- Exemple: network of sensors
  - Internals of each sensor (microseconds)
  - Communication on the network (seconds)

Refinement

- Replace a process with a more detailed version
- Do not change the observable behavior

Reactive domains

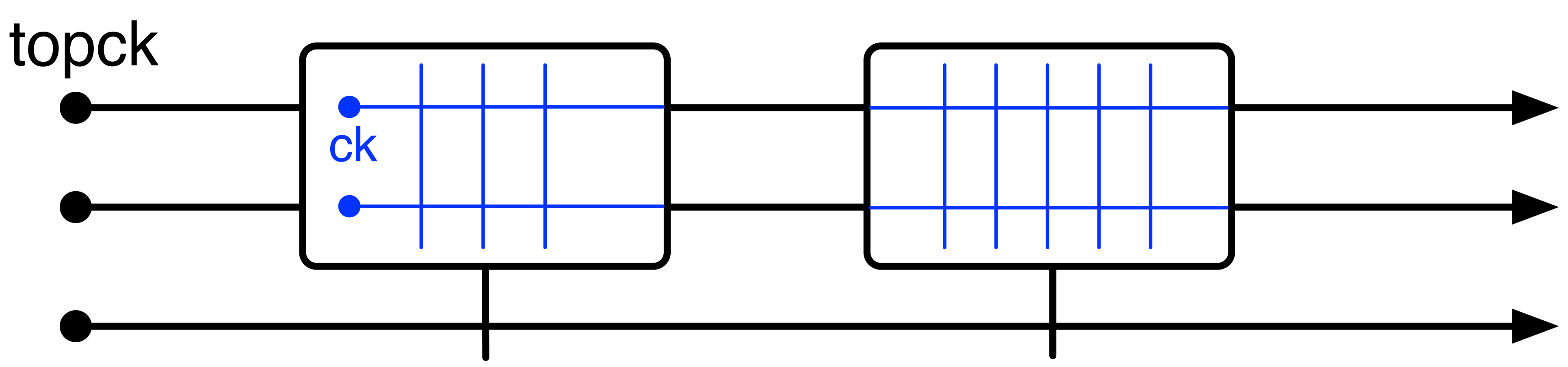
- Local instants
- Invisible from the outside of the domain



N-body improved

Multiple steps integration methods

- eg Runge-Kutta
- one computation step = one local instant
- Switch method on-the-fly



N-body improved

Adaptive integration

- Compute in several steps
  - New positions
  - Estimate of the error
- If error too big, take a smaller time step

Two reactive domains

- One for computation steps
- One for the different tries

Time and Events

Course by Gerard Berry, College de France

First lesson

- L'informatique du temps et des événements
- March 28th 2013 18:00

Courses and seminars

- On Tuesdays, at 10:00

Conclusion

Programming languages should deal with

- Time
- Concurrency

Links

- ReactiveML (http://rml.lri.fr)
- Try ReactiveML online (http://rml.lri.fr/tryrml)