

# The genesis of Lustre

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- 1 Prehistory
- 2 Birth and childhood
- 3 The industrial adventure
- 4 Twenty years of research
- 5 The language at work

# Prehistory...

- **1979-80** : Joint work on a contract with CROUZET (now Thales) on design methodology for **real-time** embedded software (case study: **avionic** anemometer)
- **1980-84** : Joint work on a formalism for specifying and reasoning about time behaviors of systems
  - **event** = increasing **sequence of dates** (continuous or discrete time)
  - **variable** = event + **sequence of values**
  - + many formal tools (counters, formal power series, ...)
- Paul was also working on dependability (with E. Pilaud, J. Pulou, ...)

...in a peaceful atmosphere

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- These **data-flow** formalisms enjoy some nice properties:  
simple formal (functional and temporal) semantics, implicit parallelism

# Birth and childhood

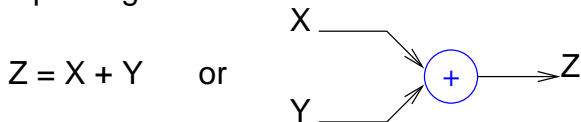
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Specialize our formalism into a programming language  
(discrete time, executable semantics)

# Paul's basic idea (cont.): Lustre in 3 slides

The dataflow paradigm:



means  $\forall t, Z(t) = X(t) + Y(t)$

Variables are functions of time.

Discrete time: **Variable = sequence of values + clock**

$x_n$ : value of  $X$  at “instant”  $n$  of its clock.

## Paul's basic idea: Lustre in 3 slides (cont.)

Program = system of **equations** :  $x = \text{exp}$

Expressions made of constants (constant sequences), variables, usual operators and **temporal operators**:

$$\text{pre}(x) = (\text{nil}, x_0, x_1, \dots, x_{n-1}, \dots)$$

$$x \rightarrow y = (x_0, y_1, y_2, \dots, y_n, \dots)$$

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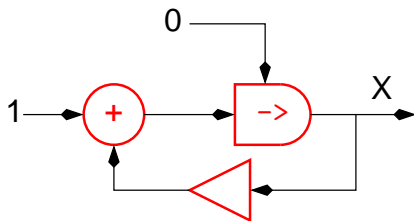
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Example:

$$x = 0 \rightarrow (\text{pre}(x) + 1)$$



# Paul's basic idea: Lustre in 3 slides (end)

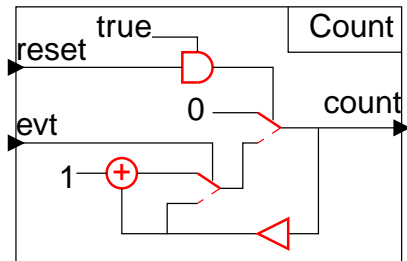
## Program structure

```

node Count(evt, reset: bool)
  returns (count: int);
let count = if (true -> reset)
  then 0
  else if evt then
    pre(count)+1
  else pre(count)

```

tel



# Paul's basic idea: Lustre in 3 slides (end)

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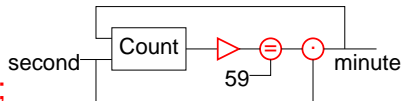
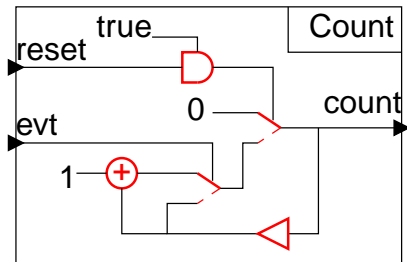
tel

## Functional call:

```

nb_sec = Count (second, minute);
minute = true ->
  second and (pre(nb_sec)=59);

```



# End of childhood

- First definition of the language: Jean-Louis Bergerand's thesis [1986]
- A very favourable context:
  - the synchronous community
  - the industrial demand

# The community of synchronous languages

Competition/cooperation with Esterel and Signal teams

- 3 languages born in France, roughly at the same time
- inspired from [Milner81], [Harel83]
- all designed by teams merging competences in **control theory** and **computer science**

{ Jean-Paul Rigaud  
Jean-Paul Marmorat } and Gerard Berry for Esterel

Albert Benveniste and Paul Le Guernic for Signal

Paul and me for Lustre

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# The industrial adventure

**Strong industrial challenges** for embedded software in the eighties (especially in France):

- Control of nuclear power plants: the **SPIN** system (Nuclear Integrated Protection System)
- Avionics: **A320**, first full “fly-by-wire” aircraft
- Ground transportation: **TGV**, **VAL**, . . .

# The industrial adventure (cont.)

- 1984-85 :
  - Schneider-Electric designs the SPIN
    - **SAGA**, an inhouse design environment based on **Lustre**:  
graphical editor, automatic code generation
    - 2 members of our team (Eric Pilaud and Jean-Louis Bergerand) move to Schneider
  - Aerospatiale designs the A320 → **SAO**

# The industrial adventure (cont.)

- 1988-89 :  
Schneider-Electric, Aerospatiale and the Verilog company set up a consortium for the development of **SCADE** (“Safety Critical Applications Development Environment”), an extended commercial version of SAGA.  
  
1 member of our team (Daniel Pilaud) moves to Verilog.

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Esterel-Technologies (2000).

Strong technical and commercial development.

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# Twenty years of research (in the team)

## Language and extensions

- Language definition and formal semantics  
[Caspi, Halbwachs, Bergerand 86, D. Pilaud]
- Mixed imperative/dataflow extensions  
[Maraninchi, Vachon-Jourdan 94, Rémond 01]
- Arrays  
[Rocheteau 92, Maraninchi, Morel 05]
- Higher-order extensions  
[Caspi, Pouzet, ...]

# Twenty years of research (cont.)

## Compilation

- to sequential code  
[Halbwachs, Plaice 88, Raymond 91, Rocheteau 92]
- to distributed and non-sequential code  
[Caspi, Buggiani 89, Girault 94, Salem-Habermehl 01, Curic 04, Scaife, Sofronis 06]

# Twenty years of research (cont.)

## Verification/Validation

- Automatic verification  
[Halbwachs, Glory-Kerbrat 89, Ratel 91, Raymond, Lesens 97, Jeannet 00, Merchat 05]
- Program proof and derivation  
[Caspi, Dumas-Canovas 00, Mikac 05]
- Automatic testing  
[Raymond, Halbwachs, Jahier, Weber 98, Pace, Roux 04]  
and debugging  
[Maraninchi, Gaucher 03]

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# What worked as expected

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... precisely, Paul's initial idea!!

- synchronous data-flow
- abstract formal semantics
- automatic code generation (single loop)

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# What did not work as expected

- **explicit automata** (for the code)
- **clocks** (in Lustre) vs. **activation conditions** (in Scade)  
Restrictive use of the notion of clock, simpler to understand
- unexpected **compilation constraints**:  
node **inlining** often forbidden
  - code readability
  - separate compiling

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Generally, users don't mind adding some “pre”

- **causality** (and conditional dependencies)
- **separate compiling**: forbid instantaneous feedback of node outputs to inputs

- Unexpected “qualities”

- program structure, user-defined operators  
(opposed to libraries of predefined operators)
- **compiler** efficiency
- detection of instant loops

# Mitigated results about formal verification

- observers well accepted  
(and adopted by **Prover** in Scade-verifier)
- **what do you want to verify?**  
Expressing desired properties often considered as a new task in the design process
- **Our hope:** Automated testing will pave the way to formal verification

# Credits (contributors from the Lustre team)

J.-L. Bergerand

Ch. Bodennec

B. Bugiani

P. Caspi

A. Curic

Ch. Dubois

C. Dumas

F. Gaucher

A. Girault

N. Halbwachs

E. Jahier

B. Jeannet

M. Jourdan

A.-C. Kerbrat

F. Lagnier

D. Lesens

F. Maraninchi

Y. Mikac

L. Morel

X. Nicollin

F. Ouabdesselam

G. Pace

D. Pilaud

E. Pilaud

J. Plaice

M. Pouzet

Y. Raoul

Ch. Ratel

P. Raymond

Y. Remond

Y. Roux

F. Rocheteau

R. Salem

N. Scaife

Ch. Sofronis

S. Tripakis

D. Weber