The genesis of Lustre

Nicolas Halbwachs

Verimag/CNRS
Grenoble
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 athmosphere
... in a peaceful atmosphere

- No industrial partners
... in a peaceful athmosphere

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- No scientific policy
... in a peaceful atmosphere

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- No European projects
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Birth and childhood

Paul’s basic idea

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  analog systems, switches networks, hardware...
Birth and childhood

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

\[ Z = X + Y \quad \text{or} \quad Z(t) = X(t) + Y(t) \]

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

Variables are functions of time.

Discrete time: \textit{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: \( x = \exp \)

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

\[
\text{pre}(x) = (\text{nil}, x_0, x_1, \ldots, x_{n-1}, \ldots)
\]

\[
x \rightarrow y = (x_0, y_1, y_2, \ldots, y_n, \ldots)
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Paul’s basic idea: Lustre in 3 slides (cont.)

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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)
ten

N. Halbwachs (Verimag/CNRS)
Paul’s basic idea: Lustre in 3 slides (end)

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tel

Functional call:

nb_sec = Count (second, minute);
minute = true \rightarrow
    second and (pre(nb_second)=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
1 Prehistory
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3 The industrial adventure
4 Twenty years of research
5 The language at work
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, . . .
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
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.
The industrial adventure (cont.)

- 1992-96: Vérimag common laboratory with Verilog, for the design of Scade
- 1995: SCADE qualified DO178-B for the A340/500-600
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Verilog bought by CS,
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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, Rémont 01]

- Arrays
  [Rocheteau 92, Maraninchi, Morel 05]

- Higher-order extensions
  [Caspi, Pouzet, . . .]
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]
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
What worked as expected

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

- synchronous data-flow
- abstract formal semantics
- automatic code generation (single loop)
What did not work as expected
What did not work as expected

- explicit automata (for the code)
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
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
What worked unexpectedly
What worked unexpectedly

- Unexpected “non problems”
  Generally, users don’t mind adding some “pre”
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  - causality (and conditional dependencies)
  - separate compiling: forbid instantaneous feedback of node outputs to inputs
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  Generally, users don’t mind adding some “pre”
  
  - causality (and conditional dependencies)
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- 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)*

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