Some uses of Caml in industry

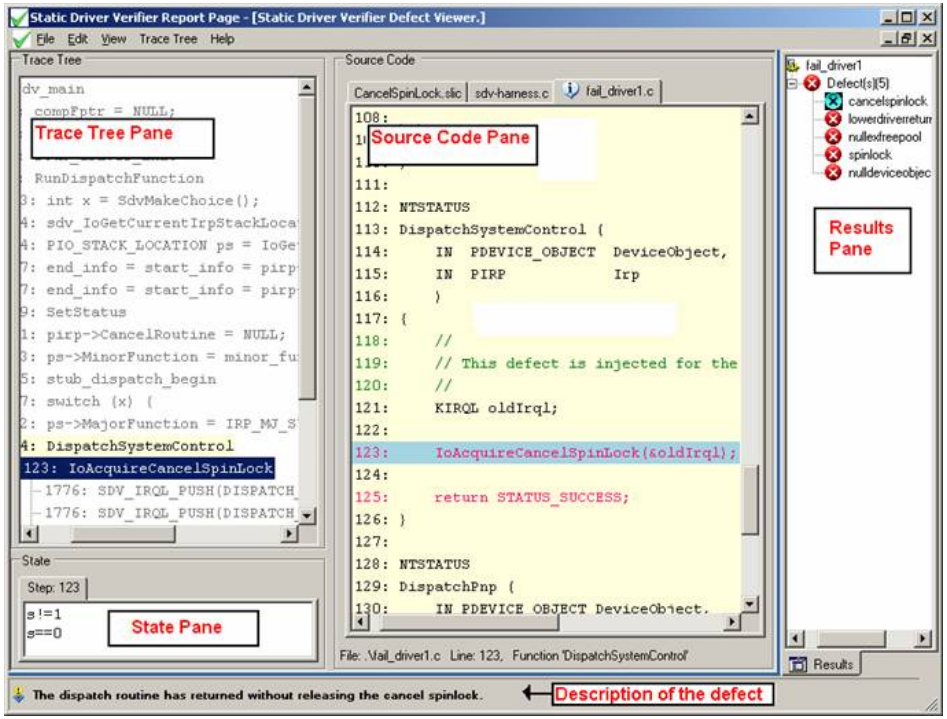
Xavier Leroy

INRIA Paris-Rocquencourt

CUFP 2007

Outline

Static Driver Verifier (Microsoft)



Static verification of Windows kernel-mode drivers, detecting violations of the Windows Driver Model API and usage rules.

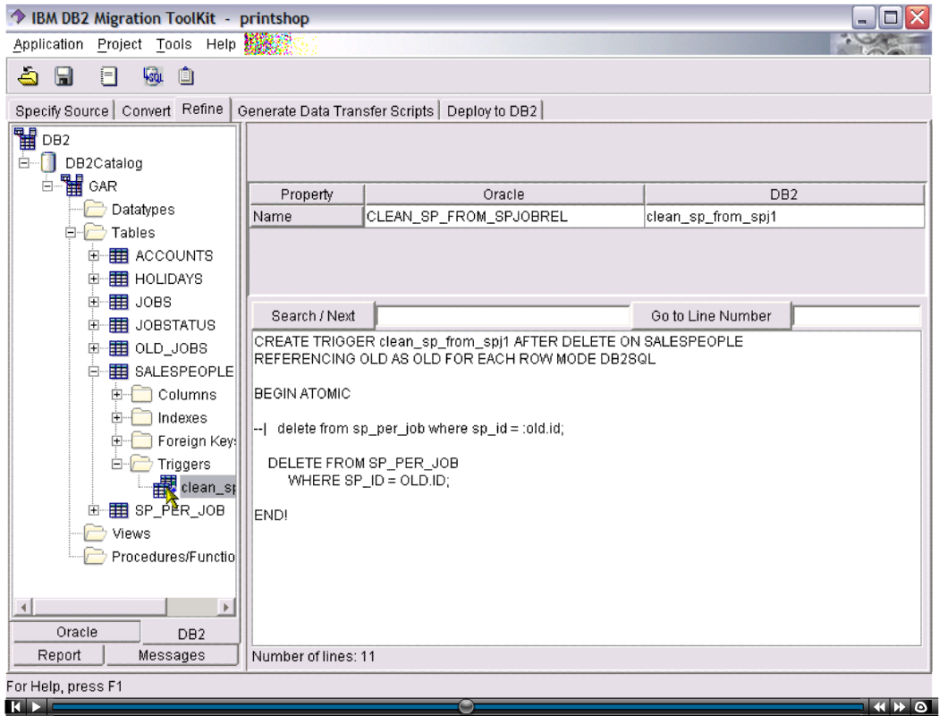
Sophisticated static analysis with model checking technology.

Distributed to developers as part of the Windows Driver Kit.

We developed SLAM using INRIA's OCaml functional programming language. The expressiveness of this language and robustness of its implementation provided a great productivity boost.

MSR-TR-2004-08, T.Ball, B.Cook, V.Levin and S.K.Rajamani

IBM Migration Toolkit

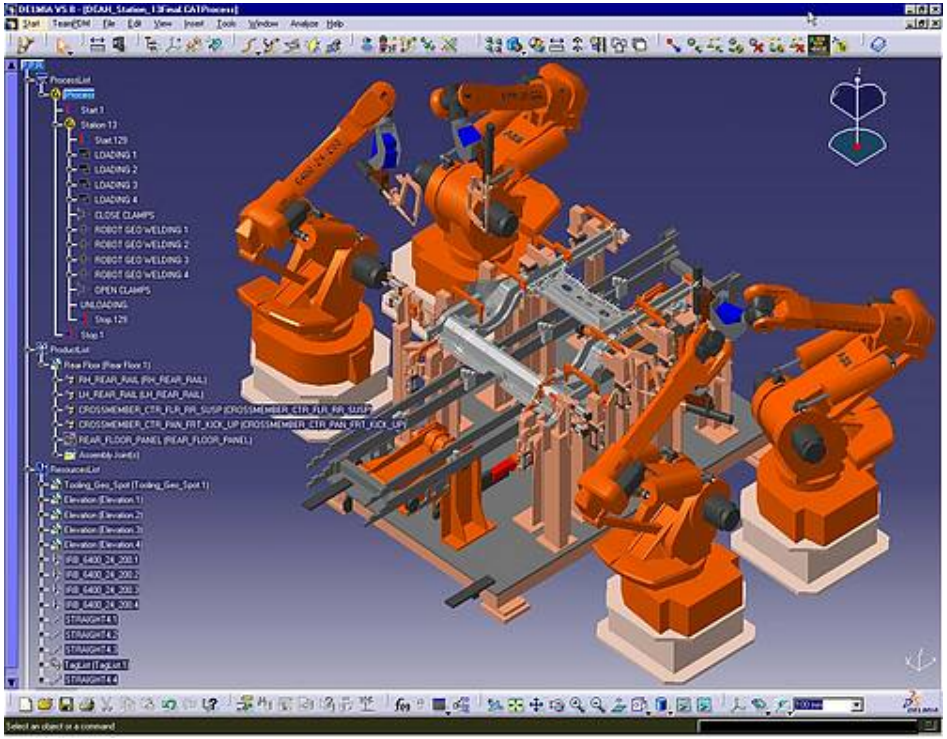


Static analysis and conversion of database schema, e.g. between DB2 and Oracle.

Compiler-like technology, generating migration scripts.

Distributed as part of IBM's Migration Toolkit.

CellControl, a component of Delmia (Dassault Systèmes)



A domain-specific language, inspired by the synchronous language Esterel, to program assembly-line automata and robots.

Developed by the Athys start-up, then integrated in the Delmia computer-aided manufacturing environment of Dassault Systèmes.

ReFLect, next generation (Intel)

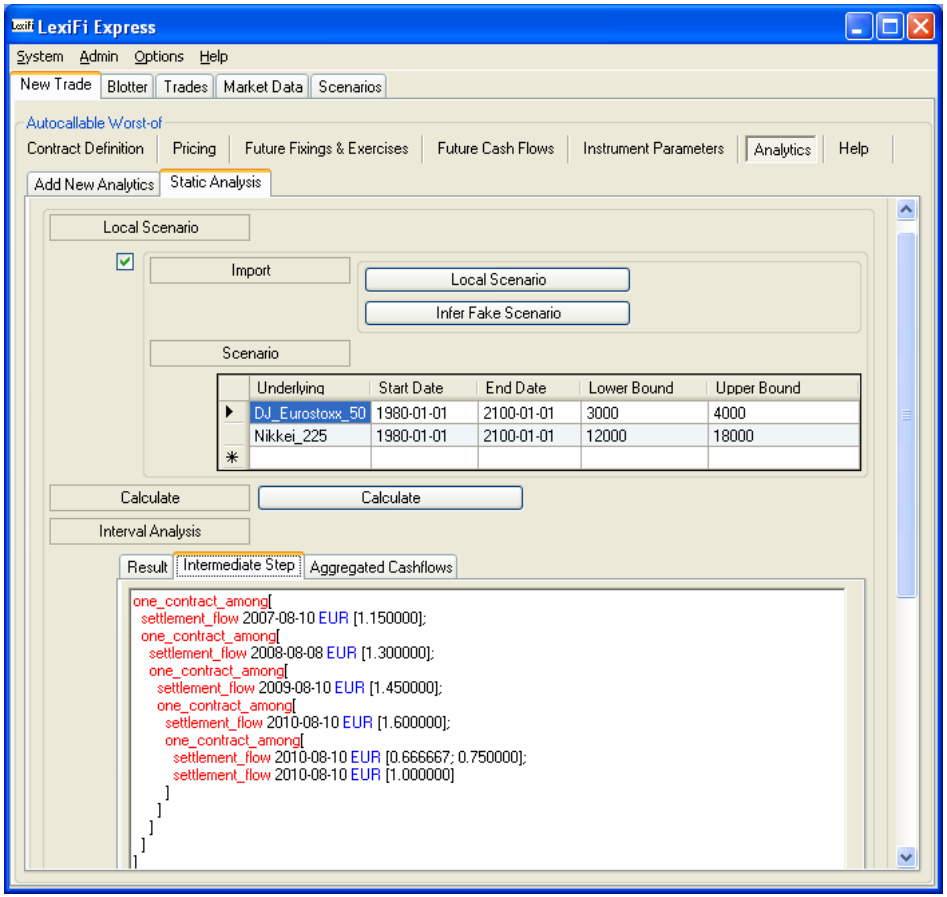
FL/reFLect: an ML-like functional language with BDDs and integrated model checking capabilities.

Used at Intel for high-level modeling and verification of circuits.

Part of the Forte environment for hardware verification.

Reimplementation in progress as a front-end for the OCaml compiler, reusing the back-end.

Modeling Language for Finance (LexiFi)



A domain-specific language for formal specification and pricing of complex financial products.

A mild extension of OCaml
+ a library of financial products
+ GUIs and interfaces with Excel, etc.

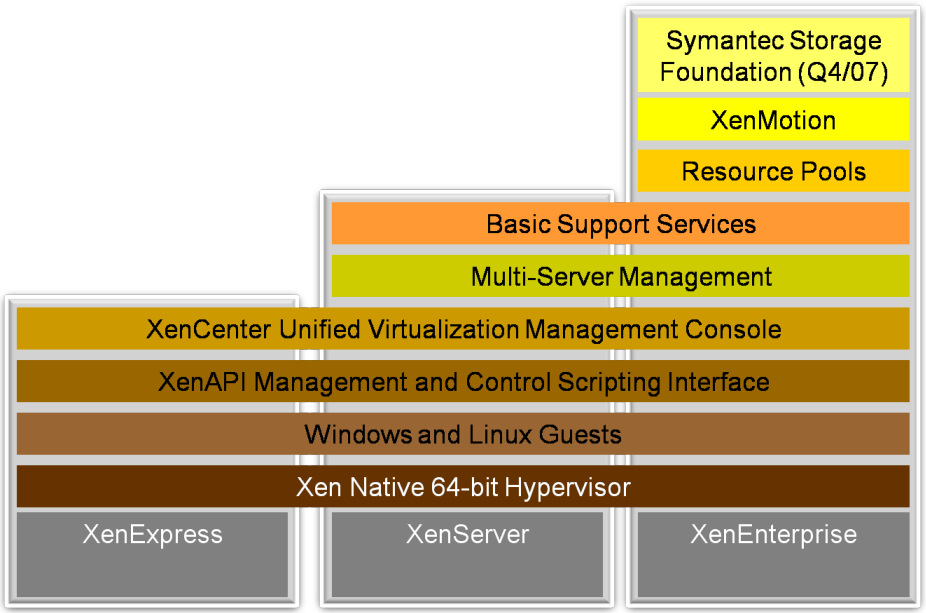
Jane Street Capital

A Wall Street trading firm, which develops in-house a lot of software for financial quantitative research, mostly in Caml.

Aggressive hiring of Caml programming talents.

Organizers and sponsors of the "OCaml summer of code" initiative.

Hypervisor systems administration tools (XenSource)



A set of systems administration tools for virtualization solutions based on the Xen open-source hypervisor.

The Astrée static analyzer (ENS)

A static program analyzer for critical embedded software, based on abstract interpretation.

Proves the absence of a large class of run-time errors, including memory violations and integer and floating-point overflows.

Used by Airbus to verify the fly-by-wire software for the A340 and A380. No false alarms!

Some general trends

The majority of Caml industrial applications revolve around programming language technologies:

- Domain-specific languages.
- Static analysis, program verification.
- Compilation, interpretation.

Occasional in-roads in systems programming, where scripting languages are typically used: XenSource, early Linspire ($\rightarrow$ Haskell).

More unconventional uses of Caml are to be found in academic projects, especially in network protocols (Ensemble groupware, Unison synchronization, MLDonkey and Peerple P2P applications, . . .).

Outline

Perceived needs of industrial users
(from a language implementor's standpoint)

Crucially important:

- Windows support.
- Linux/BSD support.
- x86 64-bit support.
- Stability, stability, more stability.
- Foreign-function interface.
- For some uses (e.g. static analysis): execution speed, moderate memory requirements.

Perceived needs of industrial users
(from a language implementor's standpoint)

Unimportant:

- GUI toolkits.
- Rich (as in Perl-rich) libraries in general.
- Yet another integrated development environment.

Durability

The age-old question: "what if (Xavier | Simon | ...) gets run over by a bus?"

Frequently asked question in the 1990's, less so nowadays.

Being open source software helps.

Having been around longer than Java helps.

Could some official commitment from a reputable institution help?

The Caml consortium

An attempt to (lightly) formalize our relations with industrial users.

Initial goals:

- A place for serious industrial users to meet and discuss.
- Collect funds to pay for a full-time programmer at INRIA.
- Yearly meetings to decide on new directions and developments, esp. what this programmer should work on.
- Low membership fees.
- Expected about 20 members.

Inspired by the Python consortium, itself inspired by the Web consortium.

The Caml consortium

What we ended up with:

- Only 6 members today, not enough to fund a full-time programmer.
- Very few requests for specific developments.
- The most tangible benefit for members is that they benefit from more liberal licensing conditions:
  - Non-members: a somewhat restrictive open-source license
  - Members: a "free for all uses" license.

Current members of the Caml consortium

	Licensing conditions	General sponsorship
Dassault Aviation		✔
Dassault Systèmes	✔	
Intel		✔
LexiFi	✔	
Microsoft	✔	
XenSource	?	?

Lessons learned from the Caml consortium

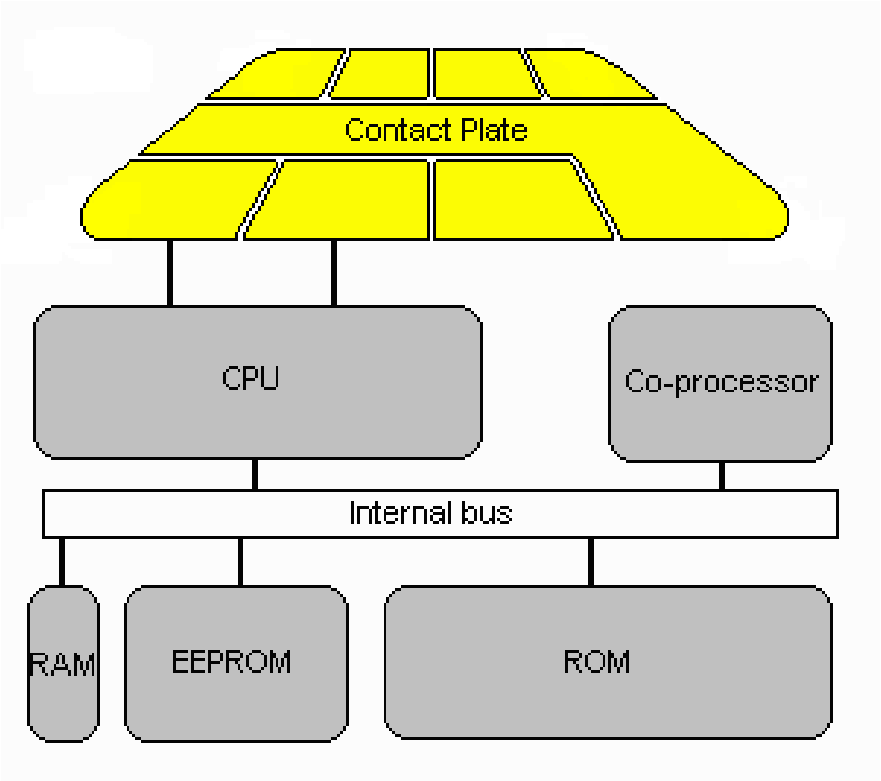
Dual licensing is a good solution
(except for integrating external contributions).

Not much interest in identifying developments useful for several members, and sharing the costs.

It's hard to have something to sell.

Outline

Smart cards



A tiny computer, usable as a security token:

- Low resources, inexpensive.
- Highly secure against software and hardware attacks.

Programming smart cards

10 years ago:

- Closed, propietary architectures.
- Programs developed by card manufacturers.
- Written in assembler or C.

Nowadays:

- Standardized, mostly open software architectures: MultOS, Java Card.
- Programming no longer restricted to manufacturers.
- The Java Card subset of Java.

The Trusted Logic company

Founded in 1999 with the intention of becoming an independent provider of software and solutions for smart cards and other secure embedded systems.

Security evaluation and consulting ($\rightarrow$ Trusted Labs company):

- Common Criteria analyses;
- formal methods and verification;
- testing, testing tools.

High-security software components

- for smart cards;
- for card readers and terminals;
- for mobile phones.

Software components for smart cards

- Low-level system components:
  management of persistent memory; cryptographic libraries.
- Java Card:
  virtual machine, run-time environment, APIs.
- The Global Platform protocols:
  secure communication channels, key management.
- Applications:
  EMV payment, ...

Programming languages used at Trusted Logic

- For on-card, embedded code:
  C, occasional bits of assembler;
  Java Card
- For off-card code, e.g. development and verification tools:
  mostly Java;
  one product written in Caml (test generation and administration).

The Java Card subset of Java

or: how to bastardize a programming language

"Just like" Java, except:

- Fewer numerical types: no `float`, no `double`, no `long`; `int` is optional
  $\longrightarrow$ compute with `short`.
- Objects allocated in persistent memory
  $\longrightarrow$ objects as storage; transactions.
- No garbage collection
  $\longrightarrow$ allocate all needed space at installation-time; work in-place; little object-orientation.

A sample of Java Card code

```
private void credit(APDU apdu) {
    if ( ! pin.isValidated())
        ISOException.throwIt(SW_PIN_VERIFICATION_REQUIRED);
    byte[] buffer = apdu.getBuffer();
    byte numBytes = buffer[ISO7816.OFFSET_LC];
    byte byteRead = (byte)(apdu.setIncomingAndReceive());
    if (byteRead != 1) ISOException.throwIt(ISO7816.SW_WRONG_LENGTH);
    byte creditAmount = buffer[ISO7816.OFFSET_CDATA];
    if ( (creditAmount > MAX_TRANSACTION_AMOUNT) || ( creditAmount < 0 ) )
        ISOException.throwIt(SW_INVALID_TRANSACTION_AMOUNT);
    if ( (balance + creditAmount) > MAX_BALANCE )
        ISOException.throwIt(SW_EXCEED_MAXIMUM_BALANCE);
    balance = (short)(balance + creditAmount);
}
```

Opportunities for functional programming?

F.P. on-card:

- Not enough resources.
- "Java Card-ization" impossible for F.P.L.

F.P. on card terminals:

- Technically feasible.
- Which applications?

F.P. in development environments:

- A need for custom development tools.
- A classic match for F.P.

The need for custom development tools

C compilation and pre/post-optimization:

- Low quality of vendor-supplied C compilers.
- Temperamental 8-bit target architectures (e.g. 8051).

Verification and transformation on Java Card VM bytecode:

- Optimizing bytecode for size.
- Verification of API conformance, security properties, ...

Domain-specific languages and C / Java Card code generators:

- The example of APDU parsing

Application Protocol Data Units (APDUs)

The VERIFY command message is coded according to Table I - 24:

Code	Value
CLA	'00'
INS	'20'
P1	'00'
P2	Qualifier of the reference data (see Table I-33)
Lc	var.
Data	Transaction PIN Data
Le	Not present

Table I - 24- VERIFY Command Message

Table I-33 defines the qualifier of the reference data (P2):

b8	b7	B6	b5	b4	b3	B2	b1	Meaning
0	0	0	0	0	0	0	0	As defined in ISO/IEC 7816-4 [1]
1	0	0	0	0	0	0	0	Plaintext PIN, format as defined below
1	0	0	0	0	x	x	x	RFU for this specification
1	0	0	0	1	0	0	0	Enciphered PIN, format as defined in Book 2
1	0	0	0	1	0	x	x	RFU for this specification
1	0	0	0	1	1	x	x	RFU for the individual payment systems
1	0	0	1	x	x	x	x	RFU for the issuer

Table I - 25- VERIFY Command qualifier of reference data (P2)

Low-level, packet-based communication protocols between card and reader.

- Poorly specified protocols.
- Vulnerable to deadlocks.
- Hand-written parsers.
- Bugs in parsers can be security risks.

No APDU parser generator that I know of.
No formal language to specify APDU protocols that I know of.

Outline

Concluding remarks

Caml in particular and F.P. in general are quite successful in the area of programs that manipulate programs
(program verification and transformation, . . .)

This area is industrially relevant.

This is a niche, but an active, technologically important niche.

Still looking for other such niches . . .

Concluding remarks

Caml in particular and F.P. in general are quite successful in the area of programs that manipulate programs
(program verification and transformation, . . .)

This area is industrially relevant.

This is a niche, but an active, technologically important niche.

Still looking for other such niches . . .

Concluding remarks

Caml in particular and F.P. in general are quite successful in the area of programs that manipulate programs
(program verification and transformation, . . .)

This area is industrially relevant.

This is a niche, but an active, technologically important niche.

Still looking for other such niches . . .

Concluding remarks

Caml in particular and F.P. in general are quite successful in the area of programs that manipulate programs
(program verification and transformation, . . .)

This area is industrially relevant.

This is a niche, but an active, technologically important niche.

Still looking for other such niches . . .