A Brief Overview of Process Calculi

SCCS Research Colloquium

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My goals today

In a nutshell

— Explain what my field (formal methods) is,

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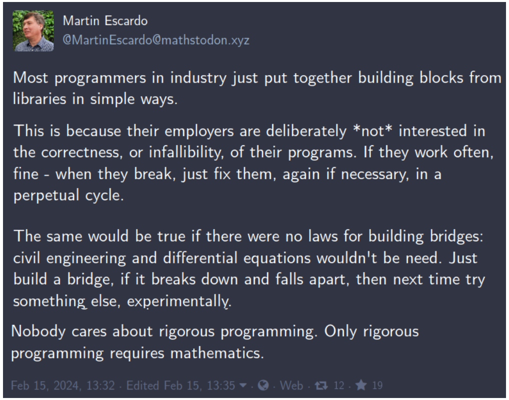
In a nutshell

- Explain what my field (formal methods) is,
- Illustrate (some of) the impacts of process calculi

Why are formal methods ignored?



Martin Escardo
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Most programmers in industry just put together building blocks from libraries in simple ways.

This is because their employers are deliberately *not* interested in the correctness, or infallibility, of their programs. If they work often, fine - when they break, just fix them, again if necessary, in a perpetual cycle.

The same would be true if there were no laws for building bridges: civil engineering and differential equations wouldn't be need. Just build a bridge, if it breaks down and falls apart, then next time try something else, experimentally.

Nobody cares about rigorous programming. Only rigorous programming requires mathematics.

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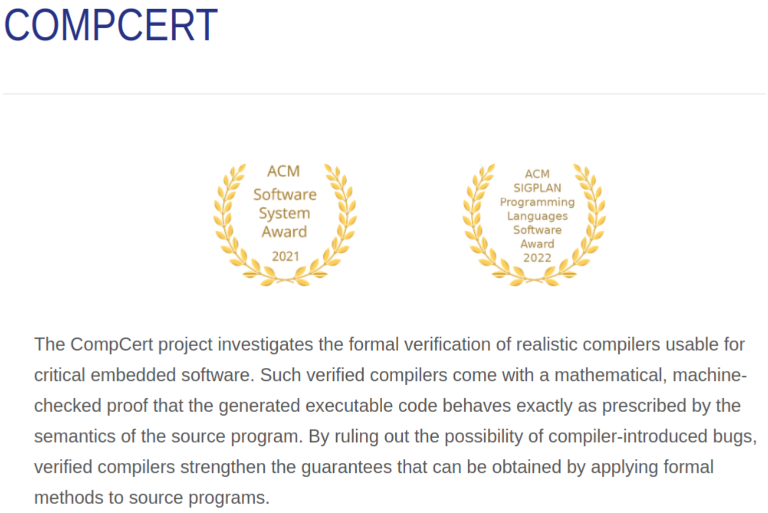
What can formal methods bring? – The example of Compcert



COMPCERT

ACM Software System Award 2021

ACM SIGPLAN Programming Languages Software Award 2022

The CompCert project investigates the formal verification of realistic compilers usable for critical embedded software. Such verified compilers come with a mathematical, machine-checked proof that the generated executable code behaves exactly as prescribed by the semantics of the source program. By ruling out the possibility of compiler-introduced bugs, verified compilers strengthen the guarantees that can be obtained by applying formal methods to source programs.

https://compcert.org/

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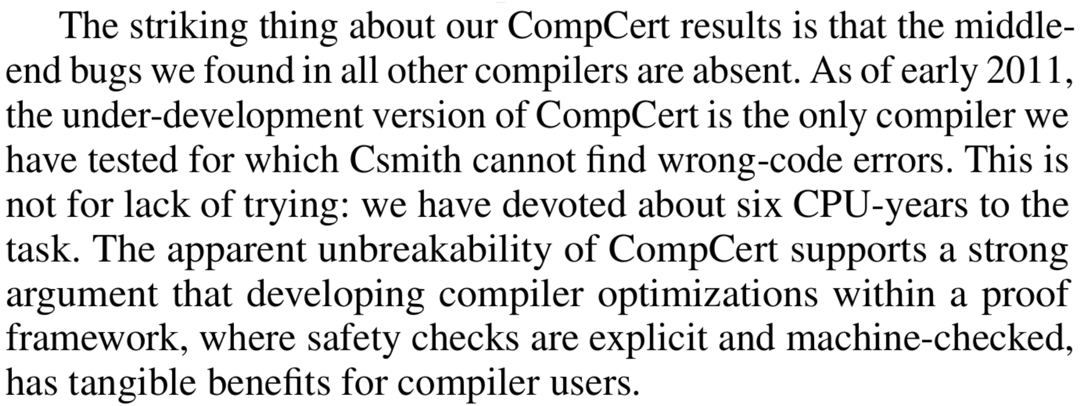

The striking thing about our CompCert results is that the middle-end bugs we found in all other compilers are absent. As of early 2011, the under-development version of CompCert is the only compiler we have tested for which Csmith cannot find wrong-code errors. This is not for lack of trying: we have devoted about six CPU-years to the task. The apparent unbreakability of CompCert supports a strong argument that developing compiler optimizations within a proof framework, where safety checks are explicit and machine-checked, has tangible benefits for compiler users.

X. Yang, Y. Chen, E. Eide, and J. Regehr. 2011. Finding and understanding bugs in C compilers. PLDI ’11, 10.1145/1993498.1993532

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Our focus today

will be on the calculus of communicating systems (CCS), introduced by Robin Milner around 1980.

CCS

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CCS

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Action and Restriction

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Calculus of Communicating Systems – Presentation

CCS

$P, Q := 0$ (*Inactive*) $\quad \alpha.P$ (*Prefix*) $\quad P\backslash\alpha$ (*Restriction*)

$P \mid Q$ (*Parallel*)

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Calculus of Communicating Systems – Presentation

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CCS

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Calculus of Communicating Systems – Applications

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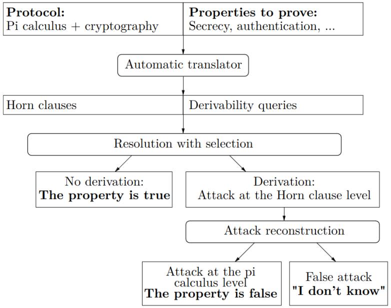

Calculus of Communicating Systems – Applications

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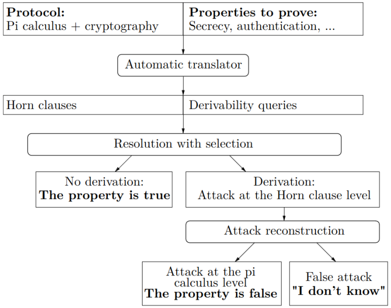
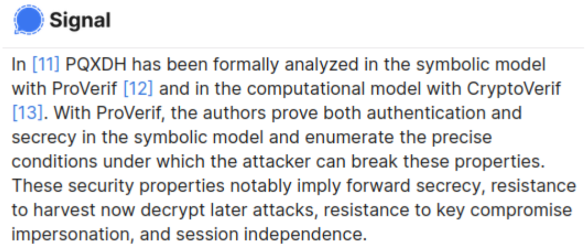


Protocol: Pi calculus + cryptography
Properties to prove: Secrecy, authentication, ...
Automatic translator
Horn clauses
Derivability queries
Resolution with selection
No derivation: **The property is true**
Derivation: Attack at the Horn clause level
Attack reconstruction
Attack at the pi calculus level **The property is false**
False attack **"I don't know"**



Signal

In [11] PQXDH has been formally analyzed in the symbolic model with ProVerif [12] and in the computational model with CryptoVerif [13]. With ProVerif, the authors prove both authentication and secrecy in the symbolic model and enumerate the precise conditions under which the attacker can break these properties. These security properties notably imply forward secrecy, resistance to harvest now decrypt later attacks, resistance to key compromise impersonation, and session independence.

CCS is also connected to . . .

Petri nets, biological systems, session types, choregraphies, category theory, . . .

Conclusion: my work & thanks!

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— "Better" applied π-calculus,

— *Reversible* CCS,

— (and others in the field of formal method, but not related to process calculi – ask Neea Rusch about those!)

Thanks!

Feel free to reach out to

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