Automated Reasoning and Artificial Intelligence

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ERC Consolidator grant

AI4REASON

European Research Council

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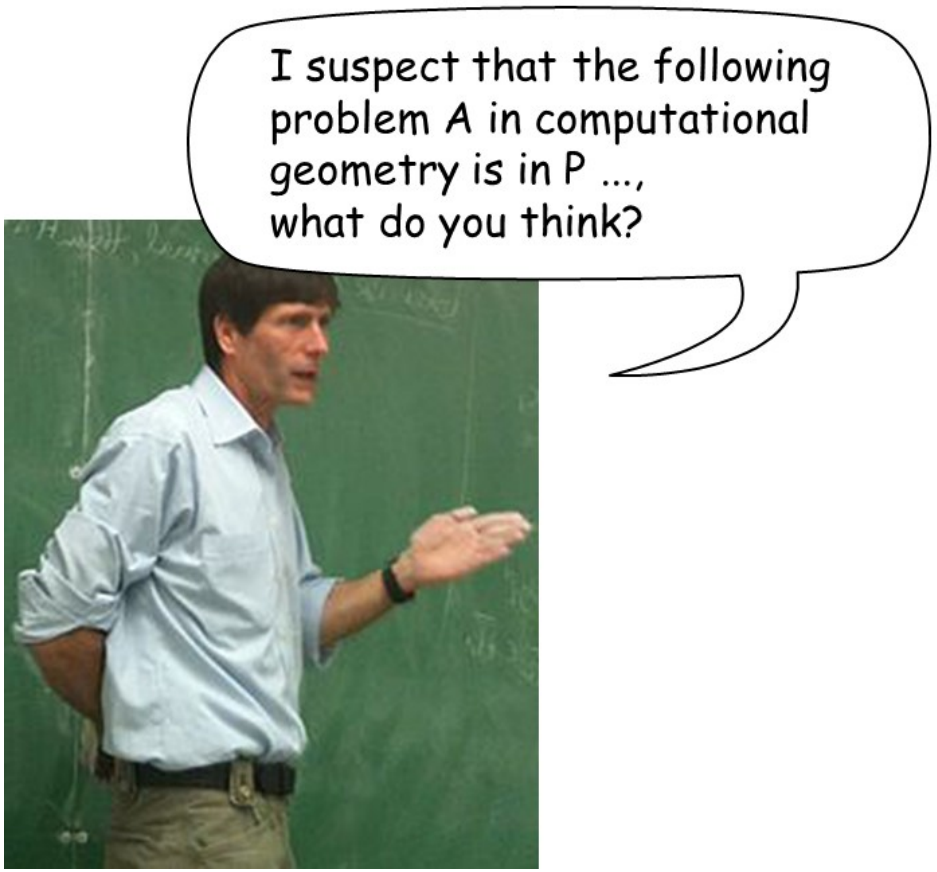
Not So Distant Future



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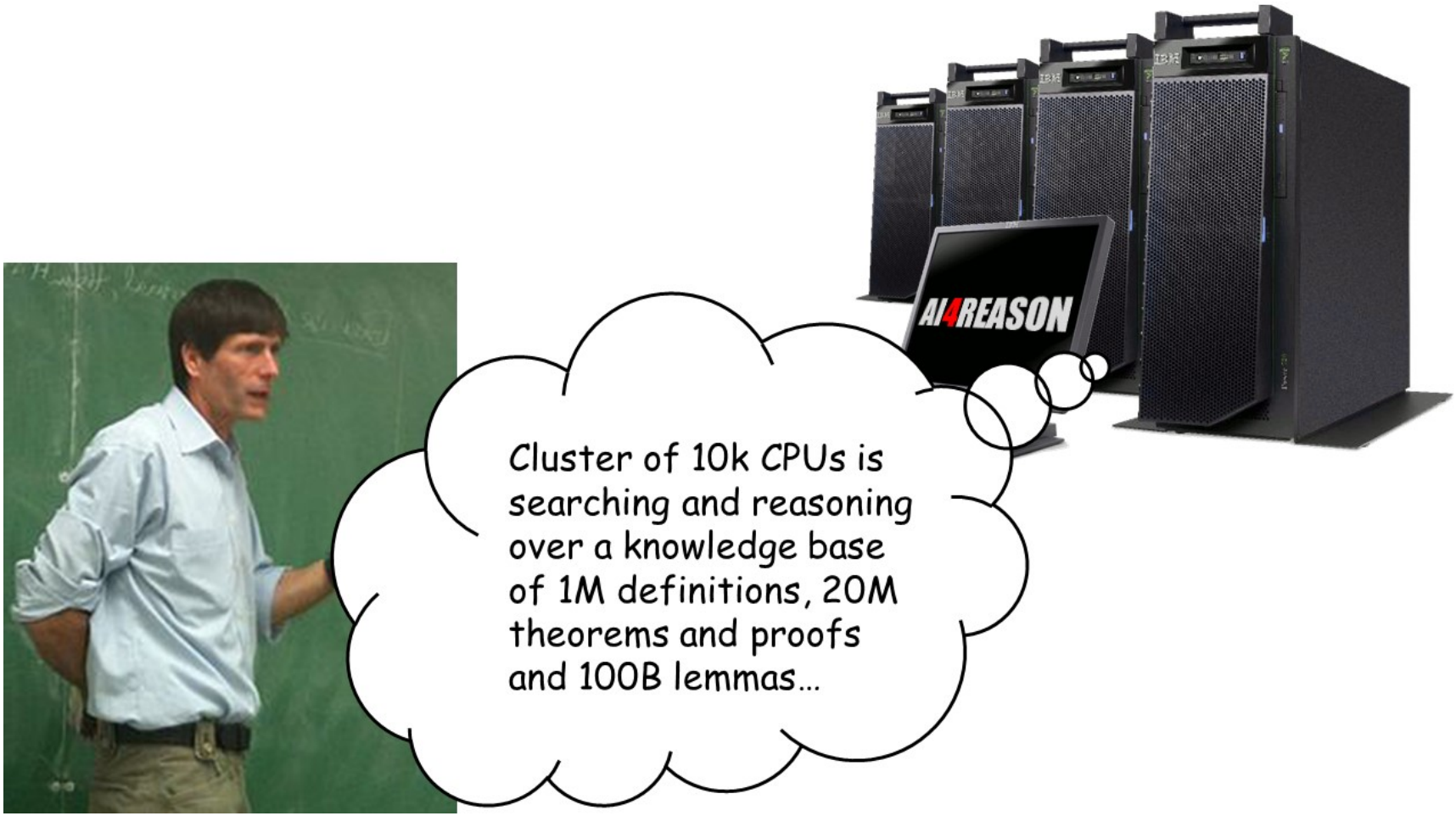

Not So Distant Future

Indeed, it is similar to a less known problem B number 13501 in my knowledge base. We can use a similar polynomial reduction to planar graphs as in B, and for the resulting constraint-solving problem we use a modified version Y of the $O(n^9)$ algorithm X published last year in Proc. of Indian Conf. on Graph Theory.

Not So Distant Future

Here is my verified formal proof with 100k basic inference steps. Here are two high-level versions of the proof, one for experts and one for textbooks.

Today: Computers Checking Large Math Proofs

SCI NEWS

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Scientists Deliver Formal Proof of Famous Kepler Conjecture

Jun 16, 2017 by News Staff / Source « Previous | Next »

Published in
Mathematics

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Johannes Kepler
Kepler conjecture

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Researchers Develop Mathematical Model for How Innovations

An international team of mathematicians led by University of Pittsburgh Professor Thomas Hales has delivered a formal proof of the Kepler conjecture, a famous problem in discrete geometry. The team's paper is published in the journal *Forum of Mathematics, Pi*.


cdn.sci-news.com/images/enlarge3/image_4960e-Kepler-Conjecture.jpg

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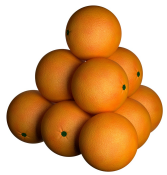
Hubble Sees Lensing Galaxy Cluster,

Kepler conjecture, Automated Reasoning and AI

- J. Kepler (1611, Prague): The most compact way of stacking balls of the same size in space is a pyramid.

$$V = \frac{\pi}{\sqrt{18}} \approx 74\%$$



- Big proof: 300 pages + computations (Hales, Fergusson, 1998)
- Formal proof finished in 2014, 20000 theorems & proofs
- All of it computer-understandable and verified
- `polyhedron s /\ c face_of s ==> polyhedron c`
- My work:
  - Learn/reason automatically over the large corpus of proofs
  - Our methods can fully automate 40% of the proofs (2014)

Today's Applications

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TECHNOLOGY NEWS 16 September 2015

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From helicopters to medical devices and power stations, mathematical proof that software at the heart of an operating system is secure could keep hackers out

Unhackable kernel could keep all computers safe from cyberattack

POPULAR

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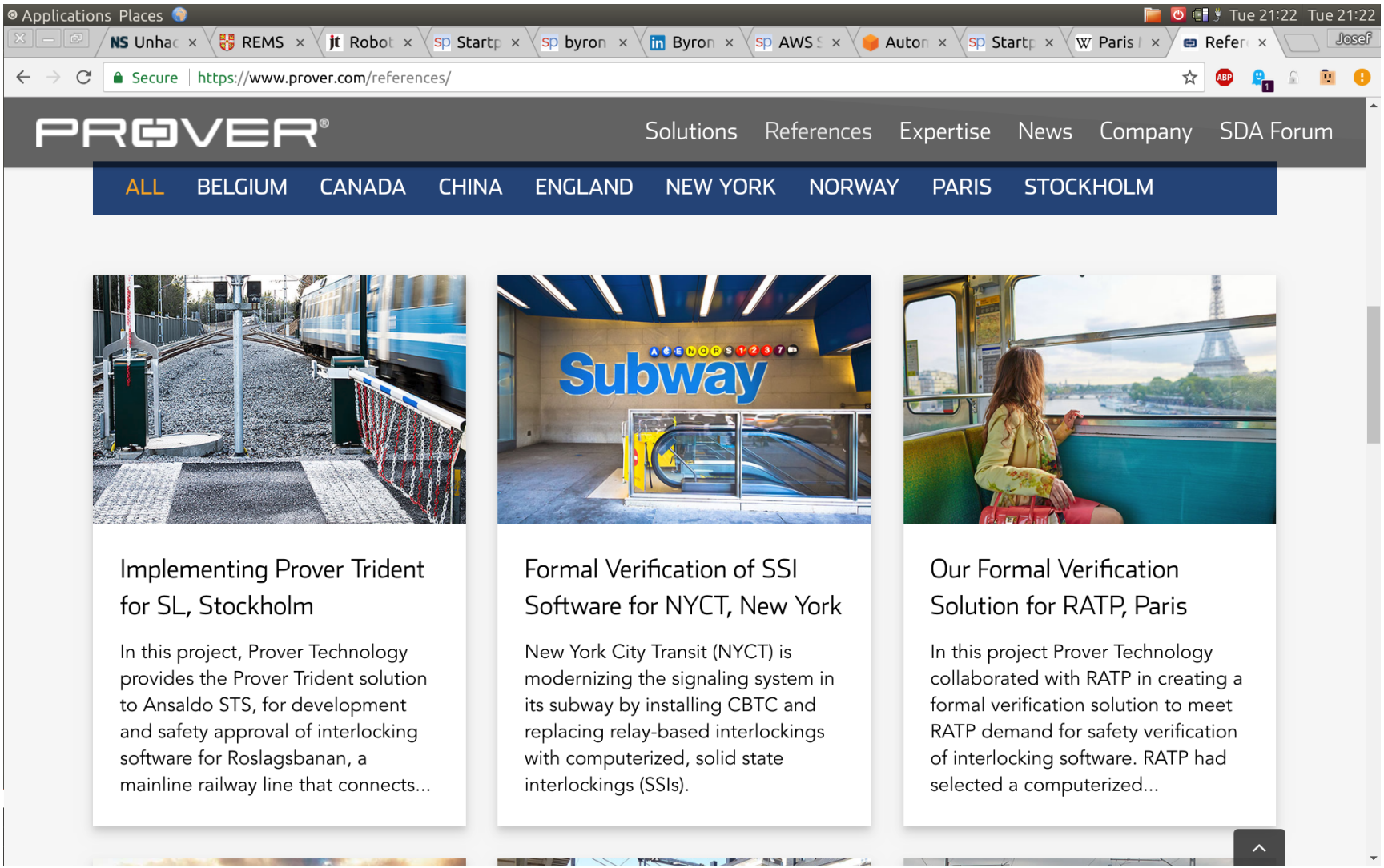
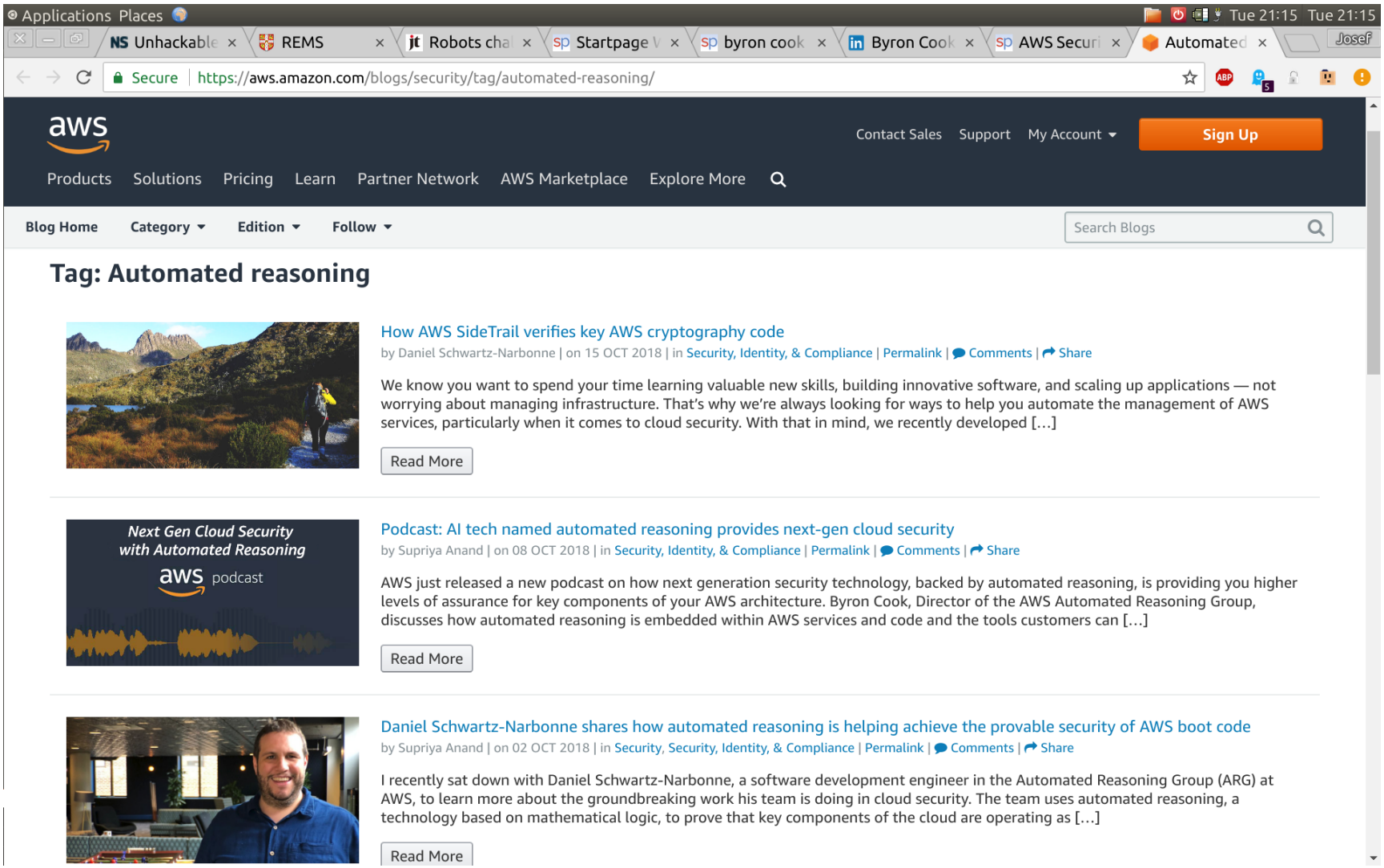


Today's Applications



Today's Applications

Applications Places — Tue 21:40 — Josef

Secure | https://www.absint.com/compcert/

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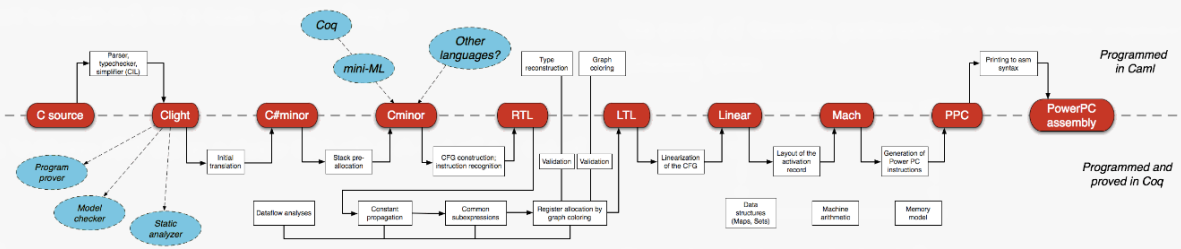
Formally verified compilation

CompCert is a formally verified optimizing C compiler. Its intended use is compiling safety-critical and mission-critical software written in C and meeting high levels of assurance. It accepts most of the ISO C 99 language, with some exceptions and a few extensions. It produces machine code for ARM, PowerPC, x86, and RISC-V architectures.

What sets CompCert apart?

CompCert is the only production compiler that is formally verified, using machine-assisted mathematical proofs, to be exempt from miscompilation issues. The code it produces is proved to behave exactly as specified by the semantics of the source C program.

This level of confidence in the correctness of the compilation process is unprecedented and contributes to meeting the highest levels of software assurance.



The formal proof covers all transformations from the abstract syntax tree to the generated assembly code. To preprocess and

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Today's Applications

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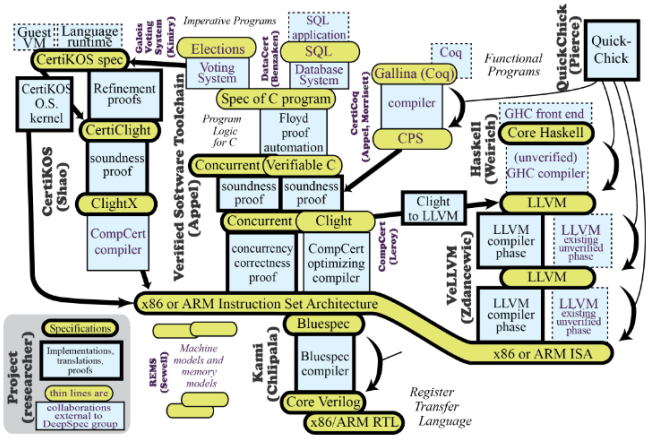
deep spec **the science of deep specification**

DeepSpec is an Expedition in Computing funded by the National Science Foundation.

We focus on the specification and verification of full functional correctness of software and hardware.

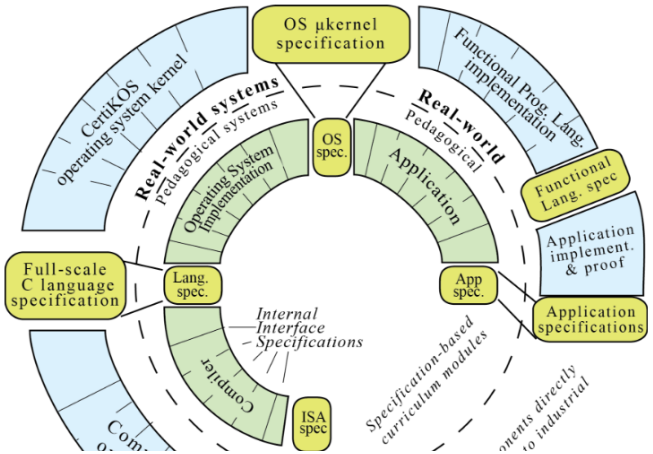
Research

We have several major research projects, and our ambitious goal is to connect them at specification interfaces to prove end-to-end correctness of whole systems.



Education

To deliver secure and reliable products, the software industry of the future needs engineers trained in specification and verification. We'll produce that curriculum.



Today's Applications

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Home » Other Sciences » Mathematics » October 12, 2012

Six-year journey leads to proof of Feit-Thompson Theorem

October 12, 2012 by Rob Knies, Microsoft

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Georges Gonthier.

At 5:46 p.m. on Sept. 20, Georges Gonthier, principal researcher at Microsoft Research Cambridge, sent a brief email to his colleagues at the Microsoft Research-Inria Joint Centre in Paris. It read, in full: "This is really the End."

Those five innocuous words heralded the culmination of a project that had consumed more than six years and resulted in the **formal proof of the Feit-Thompson Theorem**, the first major step of the classification of finite simple groups.

The theorem, first proved by Walter Feit and John Griggs Thompson in 1963 and also known as the Odd-Order Theorem, states that in mathematical group theory, every finite group of odd order is solvable.

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Future Potential - Science

- Use strong AI/reasoning and formal verification for:
- Science
  - Routinely verify complex math, software, hardware?
  - Make all of math/science computer-understandable?
  - Strong AI assistants for math/science?
- Examples
  - Automatically understand/verify/explain all arXiv papers?
  - Can we train a superhuman system like AlphaGo/Zero for math/physics? What will it take?
  - Can we prove that the Amazon Cloud cannot be hacked?
  - The same for critical government/private IT systems?

Future Potential - Society

- Use strong AI/reasoning and formal verification for:
- Society
  - Leibniz's dream: Let us Calculate! (solve any dispute)
  - J. McCarthy: Mathem. Objectivity and the Power of Initiative
  - AI/reasoning assistants for law/regulations
  - Verification of financial, transport/traffic systems, ...
  - Explainable and very securely verified systems
- Examples
  - Prove that two Paris metro trains will never crash?
  - Prove that a trading system doesn't violate regulations?
  - Prove that a new law is inconsistent with an old one?
  - Automatically debunk fallacies in political campaigns?

Possible Pitfalls and Avoiding Them

Keep informed, don't fall for the hype

- AI is much more than just (deep) learning/neural nets
- E.g., SAT/SMT/model-checking may be one of the biggest recent AI successes – Amazon, Facebook, Microsoft, etc.
- Don't expect miracles/singularity due to the current hype
- We can train image recognition & language models, but ...
- .. don't know what it takes to solve hard science problems
- However, some breakthroughs can happen quickly
- Researchers/society/lawmakers need to talk more/faster
- AI infrastructure for EU (CLAIRE) could serve this purpose

Possible Pitfalls and Avoiding Them

Don't let US, China, ...

- ... take away the best EU science minds
- In reasoning and formal methods EU is the leader!
- Make a deal with big AI companies to seriously support open university-based research
- Example: PRAIRIE institute in Paris,
- ... CLAIRE centers modelled after that?
- Infrastructure like CLAIRE very needed in countries like CR
- Larger brain-drain and local incompetence aggravating it
- Use such infrastructure to impose EU values on AI

Links and Impacts on Other AI Areas

- Main areas: Machine Learning, Automated Reasoning
- Needs advances in Representation Learning
- AI needs intuition, but also reasoning and explanations
- Impact on Formal Verification (SW, HW, etc.)
- Potentially on any (hard) science/thinking/arguing
- Alan Turing, 1950, AI:

"We may hope that machines will eventually compete with men in all purely intellectual fields."

Outlook – Scientific Revolution, AI?

- What did Kepler, Galileo & Co start to do in 1600s?
- What are we trying to do today?
- Kepler's Conjecture in Strena in 1611 (with many others)
- Kepler's laws, Newton, ..., age of science, math, machines
- ..., Hilbert, ..., Turing, ... age of computing machines?
- 1998 machine helps to find a proof of Kepler's Conjecture
- 2014 machine verifies a proof of Kepler's Conjecture
- ... 2050? machine finds a proof of Kepler's Conjecture?