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- UT Mechanized Reasoning Group
- The ACL2 system
- Interactive theorem proving (ITP)
- Formal verification

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- Simple demo of typical use: sum to \( n \)
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In essence, they prove systems correct rather than run massive tests that are woefully incomplete.

Some of those use ACL2. Others don’t yet....
Quoting Bill Gates, April 18, 2002. Keynote address at WinHec 2002


Things like even software verification, this has been the Holy Grail of computer science for many decades but now in some very key areas, for example, driver verification we're building tools that can do actual proof about the software and how it works in order to guarantee the reliability.
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INTRODUCTION (PAGE 3)

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► ACL2 programming and evaluation
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- Interfaces
  - Emacs (my preferred)
  - **ACL2 Sedan** (Eclipse-based interface)
  - None?
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Moving from specific to general....
The UT mechanized reasoning group sits on GDC 7S.
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- An ACL2 seminar typically takes place weekly; you’re invited!
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▶ Personnel
  ▶ Dr. Marijn Heule (SAT expert)
  ▶ Prof. Warren Hunt (Group leader)
  ▶ Prof. J Moore (ACL2 co-author; retired but very active)
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Example: Nathan Wetzler is completing his Ph.D. on “Efficient, Mechanically-Verified Validation of Satisfiability Solvers” (proofs about SAT using ACL2)
The ACL2 system

- Freely available, including libraries of *certifiable books*
THE ACL2 SYSTEM

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- Let’s explore the [ACL2 home page](http://www.cs.utexas.edu/users/moore/acl2/home).

History


Boyer-Moore Theorem Provers go back to the start of their collaboration in 1971.
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- Yearly ITP conference (formerly TPHOLs)
REMARK (thanks to J Moore for this):

All industrial-scale deduction tools are, in a deep sense, interactive, even the ones that claim to be automatic. The issue is HOW MUCH interaction is required to do interesting things.
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ACL2 has a long history of automating deductions.
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Other ITP systems also automate reasoning, to various degrees.
FORMAL VERIFICATION

In the context of hardware and software systems, formal verification is the act of proving or disproving the correctness of intended algorithms underlying a system with respect to a certain formal specification or property, using formal methods of mathematics.

– Quoting Wikipedia
[Sanghavi, Alok (21 May 2010). “What is formal verification?”. EE Times_Asia.]
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Formal tools include:

- equivalence checkers
- model checkers
- theorem provers (including ACL2)
- SAT solvers and SMT solvers
- static analysis tools (e.g. COMPASS, Blast, Slam)
- ...

FORMAL VERIFICATION: GROWING ITS USE


10. Automation

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9. Apply to problems that people care about

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FORMAL VERIFICATION: GROWING ITS USE


10. Automation
9. Apply to problems that people care about
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7. Support for being a friendly "proof companion"
"Top 10" list from my talk, My Top Ten Things to do for more Empirically Successful Computerized Reasoning, ESCoR Workshop, FLoC, Seattle, Aug 21, 2006.

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2. Find bugs (but only actual bugs – soundness!): gets attention

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2. Find bugs (but only actual bugs – soundness!): gets attention
1. Connections/infiltration, including management positions [i.e., social network]
FORMAL VERIFICATION WITH ACL2

ACL2 is used in industry at

Centaur, Oracle, Intel, Rockwell Collins, AMD, and IBM,
FORMAL VERIFICATION WITH ACL2

ACL2 is used in industry at Centaur, Oracle, Intel, Rockwell Collins, AMD, and IBM, as well as the U.S. Government and universities, including UT: x86 modeling project, with x86 interpreter defined in ACL2.
**Formal Verification: ACL2 modeling**

Typical ACL2-based approaches to software and hardware verification:

```lisp
(defun run (st n)
  (if (zp n) ; n is 0
     st
     (run (run1 st) ; run one instruction
       (- n 1)))
```
FORMAL VERIFICATION: ACL2 MODELING

Typical ACL2-based approaches to software and hardware verification:

- Using a *translator*: Map programs to ACL2 functions.
**FORMAL VERIFICATION: ACL2 modeling**

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  - Has been done for many years.
  - Currently used for rtl verification at Centaur.
  - Sometimes called a \textit{deep embedding}. 

\begin{verbatim}
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THE ACL2 “ECOSYSTEM”

Our Research Program

ACL2 PROJECT

ACL2 System

Application-Oriented Research

"Customers"

AMD
Galois
Intel
JPL
NI
RCI
Boeing
IBM
Centaur
Microsoft
NSA
Northeastern
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How does the prover operate, and how does one operate the prover?
**SIMPLE DEMO OF TYPICAL USE: SUM TO N**

**[DEMO]:** file demo-2.lsp  
(log demo-2-log.txt)

- Illustrates recursive definition, automated proof, rewriting
- Note that prover operation is controlled by proving theorems, which are typically stored as rules (to be applied automatically).
- The basic interaction model is "The Method": write functions, prove lemmas, react to unproved subgoals by proving rewrite rules.
PROVER AUTOMATION

► Most important:
  ► **simplification** (especially, using **rewriting**, but also linear arithmetic, boolean reasoning, . . .)
  ► **induction**
**Prover Automation**

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- Other processes: destructor elimination, heuristic use of equalities, generalization, and elimination of irrelevance.
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  [DEMO]: file rev-rev-1.lsp
  (log rev-rev-1-log.txt)

For more on rewriting, see the documentation:
ACL2
ACL2-tutorial
Introduction-to-the-theorem-prover
introduction-to-rewrite-rules-part-1
THE ACL2 WATERFALL

- Simplification
- Destructor Elimination
- Equality
- Generalization
- Elimination of Irrelevance
- Induction

User

formula

pool
PROVER CONTROL

► Hints
PROVER CONTROL

- Hints
- Rules, especially rewrite rules (about a dozen and a half kinds of rules)
PROVER CONTROL

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[DEMO]: file rev-rev-2.lsp
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Many more ways to control the prover: Meta reasoning, macros, rule-classes, . . .
PROVER CONTROL (CONT.)

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- Documentation helps, e.g.:
  - THE-METHOD
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  - DEBUGGING
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- [DEMO]: file rotate.lsp
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  (for another proof, see rotate-alt.lsp)
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ACL2 VARIANTS

▶ **ACL2(r):** support for real numbers (Ruben Gamboa)

Now part of ACL2

The following demo shows that ACL2 executes efficiently, but can be yet much faster when using function memoization.

[DEMO]: file fibonacci.lsp
(log fibonacci-log.txt)
ACL2 VARIANTS

- **ACL2(r):** support for real numbers (Ruben Gamboa)
- **ACL2(p):** support for parallel evaluation and reasoning (David Rager)
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  - Theory $T_1$ is a conservative extension of theory $T_0$ if every theorem of $T_1$ in the language of $T_0$ is a theorem of $T_0$. 

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FOUNDATIONS

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IMPLEMENTATION

ACL2 is written mostly in itself (!).
IMPLEMENTATION

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Example, time permitting: we’ll look at the code for a substitution function, sublis-var.
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- For more information:
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Bill Gates again, this time at the dedication of our building, the Gates Dell Complex: 1 minute 33 seconds on how the greatest challenge for CS in the years ahead is “verifying correctness”:
https://www.youtube.com/watch?v=UOPWydeC6a0&t=2219