Introduction to ACL2

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April 21-23, 2015

Outline

Introduction

Context

Prover Automation and Control

ACL2 Variants

Foundations

Implementation

Conclusion

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

Prover Automation and Control
- Simple demo of typical use: sum to n
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Some of those use ACL2. Others don't yet....

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Quoting Bill Gates, April 18, 2002. Keynote address at WinHec 2002
[http://research.microsoft.com/en-us/projects/slam/]

> *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.*

Introduction (page 3)

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- Interfaces
  - Emacs (my preferred)
  - ACL2 Sedan (Eclipse-based interface)
  - None?

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Moving from specific to general....

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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)

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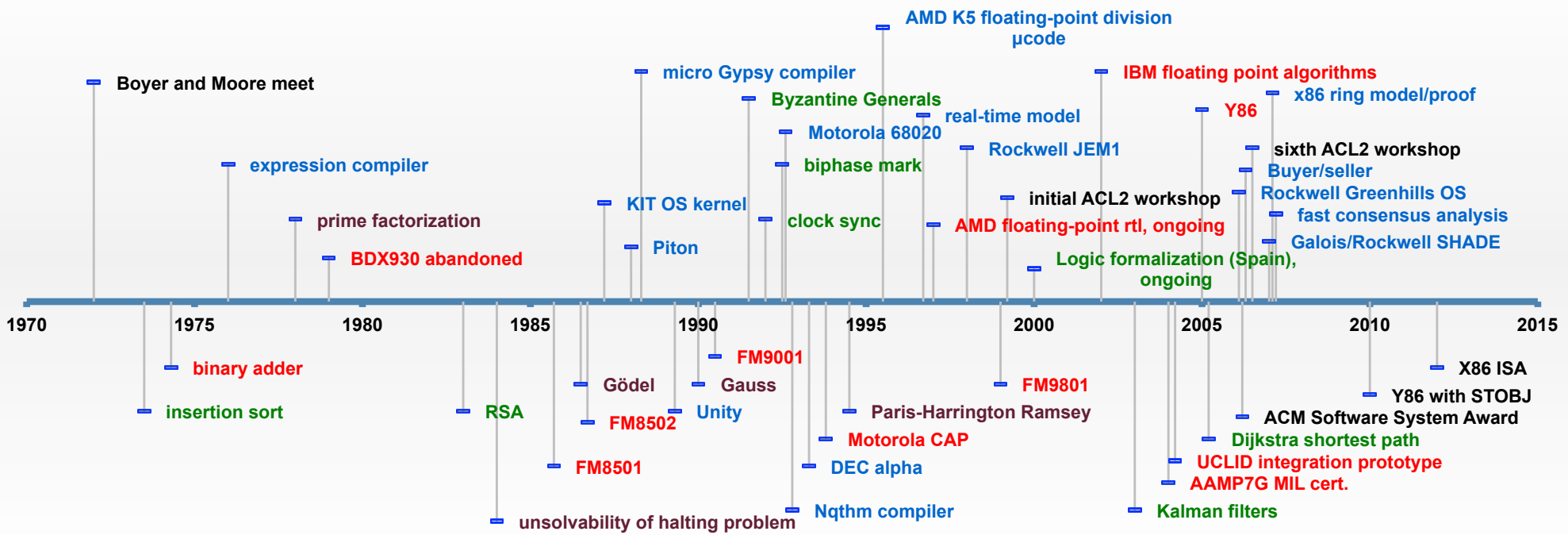
  - *Boyer-Moore Theorem Provers* go back to the start of their collaboration in 1971.

Partial timeline



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- Yearly ITP conference (formerly TPHOLs)

ITP (PAGE 2)

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Other ITP systems also automate reasoning, to various degrees.

Formal Verification

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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

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1. Connections/infiltration, including management positions [i.e., social network]

Formal Verification with ACL2

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as well as the **U.S. Government** and **universities**,

including UT:

x86 modeling project, with x86 interpreter defined in ACL2.

Formal Verification: ACL2 modeling

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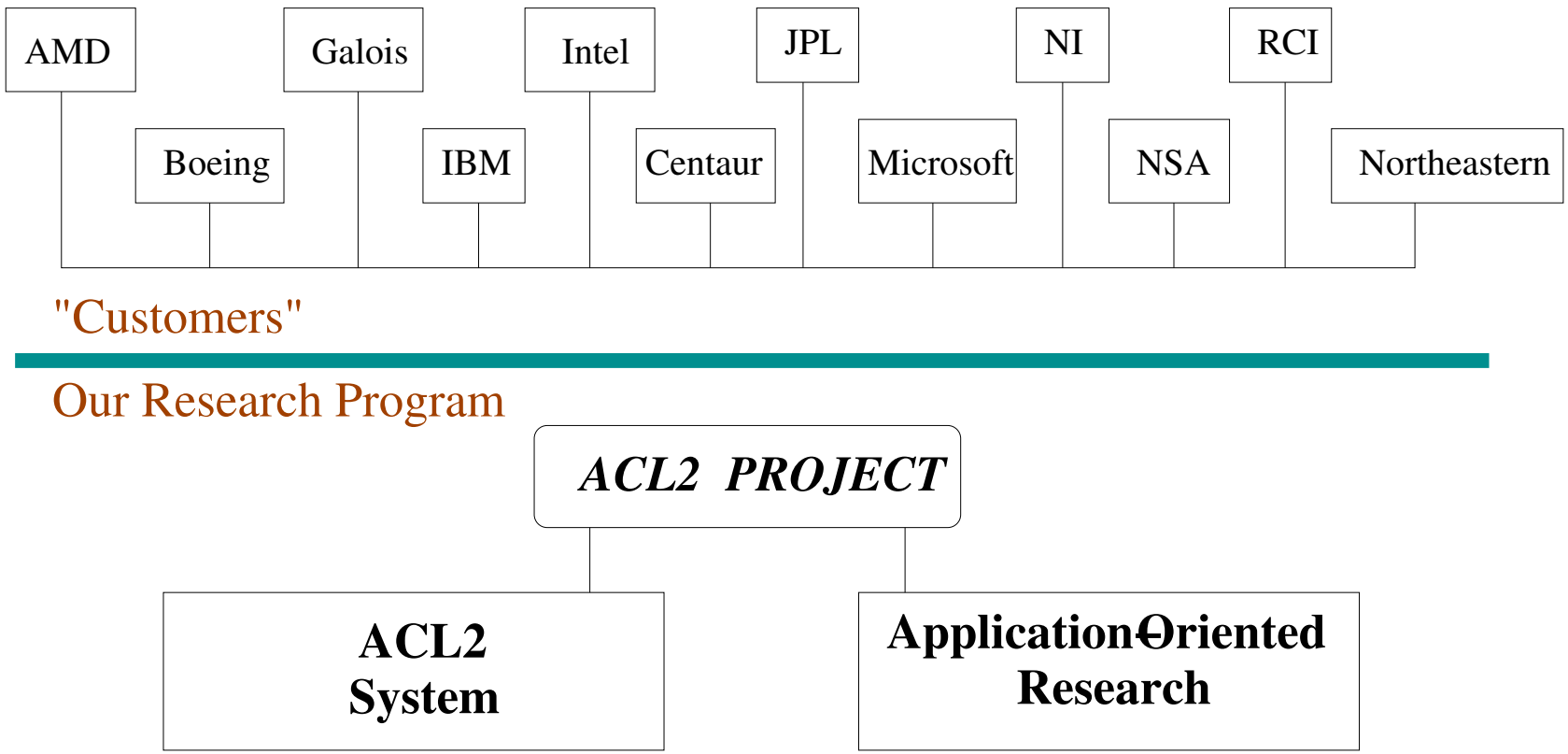
```
(defun run (st n)
  (if (zp n)              ; n is 0
      st
    (run (run1 st)        ; run one instruction
         (- n 1))))
```

THE ACL2 "ECOSYSTEM"



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Prover Automation and Control

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.

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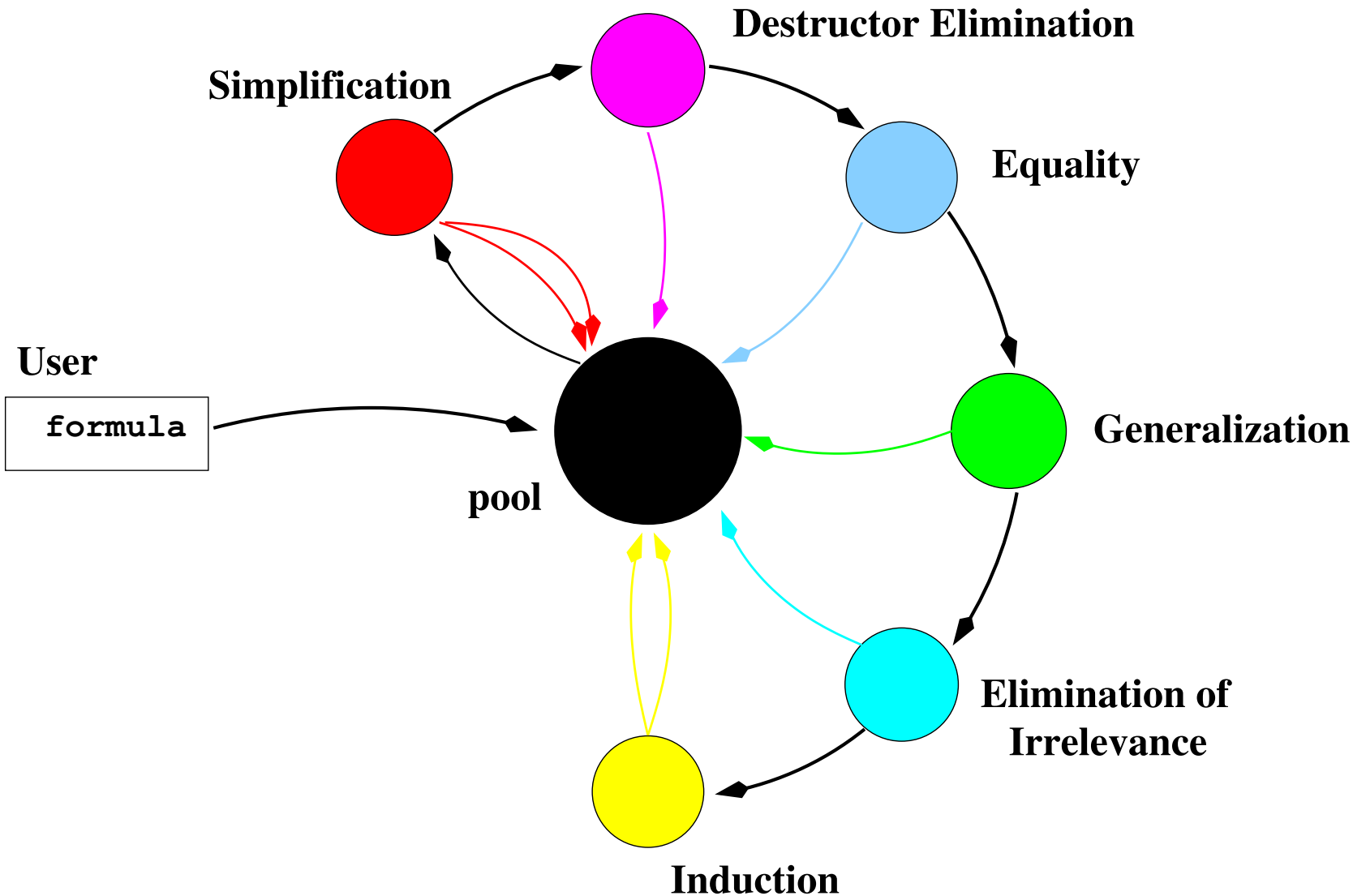
- Other processes: destructor elimination, heuristic use of equalities, generalization, and elimination of irrelevance.
  [DEMO]: file `rev-rev-1.lsp`
  (log `rev-rev-1-log.txt`)

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

THE ACL2 WATERFALL



Prover control

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- [DEMO]: file `rotate.lsp`
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  (for another proof, see `rotate-alt.lsp`)

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- ACL2(h): hash cons, function memoization, and applicative hash tables (Bob Boyer, Jared Davis, Warren Hunt, and Sol Swords)
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  - 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`)

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      – even by recursive definition, when termination is provable

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- Correctness of LOCAL and ENCAPSULATE:
  M. Kaufmann and J Moore, "Structured Theory Development for a Mechanized Logic." *Journal of Automated Reasoning* 26, no. 2 (2001) 161-203.

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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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  Matt Kaufmann, GDC 7.804, kaufmann@cs.utexas.edu

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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`