The QUODLIBET Project

Facts, History, and Future

Claus-Peter Wirth

What It Is

QUODLIBET is an Inductive Theorem Proving (ITP) software system

- designed to support verification and synthesis of non-trivial algorithms
- tactic-based
- built-in linear arithmetic (Presburger)
- human-oriented

Why is QUODLIBET Interesting?

Aspects superior to other ITP systems:

- Human-Orientedness
  (*Descente Infinie* + Mutual Prompting + GUI)
- Partial and Incremental Definition
  (Monotonicity w.r.t. Consistent Extension)
- Search Space Organization + Proof Re-Use

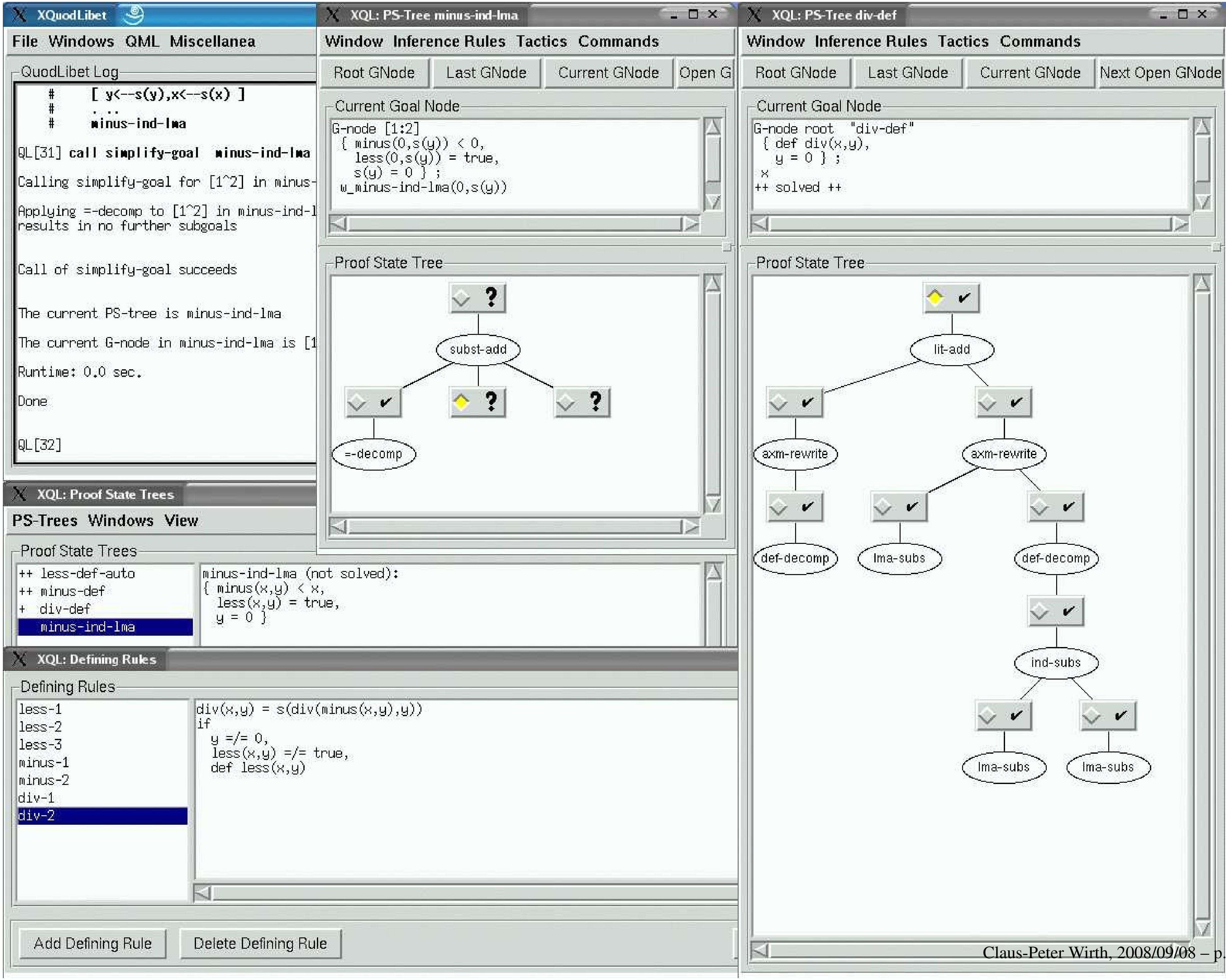
Competing Systems
(Explicit Induction only, but no *Descente Infinie*):

- ACL2 (successor of NQTHM) is so fast that it is suitable for testing in addition to proving. No GUI. No partial specification.
- PVS.

QuodLibet **provides the Flexibility...**

... needed for searching for hard induction proofs:

- Generation of induction hypotheses:
  eager / lazy / mutual
- Choice of induction ordering: eager / lazy
- Open lemmas
- Alternative proof attempts in parallel:
  forest of and/or-trees


XQuodLibet
File Windows QML Miscellanea
QuodLibet Log
[y<--s(y),x<--s(x)]
. . .
minus-ind-lma
QL[31] call simplify-goal minus-ind-lma
Calling simplify-goal for [1^2] in minus-
Applying =-decomp to [1^2] in minus-ind-l
results in no further subgoals
Call of simplify-goal succeeds
The current PS-tree is minus-ind-lma
The current G-node in minus-ind-lma is [1
Runtime: 0.0 sec.
Done
QL[32]
XQL: PS-Tree minus-ind-lma
Window Inference Rules Tactics Commands
Root GNode
Last GNode
Current GNode
Open G
Current Goal Node
G-node [1:2]
{ minus(0,s(y)) < 0,
less(0,s(y)) = true,
s(y) = 0 } ;
w_minus-ind-lma(0,s(y))
Proof State Tree
subst-add
=-decomp
XQL: PS-Tree div-def
Window Inference Rules Tactics Commands
Root GNode
Last GNode
Current GNode
Next Open GNode
Current Goal Node
G-node root "div-def"
{ def div(x,y),
y = 0 } ;
x
++ solved ++
Proof State Tree
lit-add
axm-rewrite
axm-rewrite
def-decomp
lma-subs
def-decomp
ind-subs
lma-subs
lma-subs
XQL: Proof State Trees
PS-Trees Windows View
Proof State Trees
++ less-def-auto
++ minus-def
+ div-def
minus-ind-lma
minus-ind-lma (not solved):
{ minus(x,y) < x,
less(x,y) = true,
y = 0 }
XQL: Defining Rules
Defining Rules
less-1
less-2
less-3
minus-1
minus-2
div-1
div-2
div(x,y) = s(div(minus(x,y),y))
if
y =/= 0,
less(x,y) =/= true,
def less(x,y)
Add Defining Rule
Delete Defining Rule

Contributors

- Initiators

Jürgen Avenhaus	Univ. Kaiserslautern
Klaus Madlener	Univ. Kaiserslautern
Bernhard Gramlich	TU Vienna

- Development Staff

Ulrich Kühler	1990–2000	sd&m AG
Tobias Schmidt-Samoa	1998–2006	ESG GmbH
Claus-Peter Wirth	1990–2008	Saarland Univ.

+ half a dozen of M.Sc. students

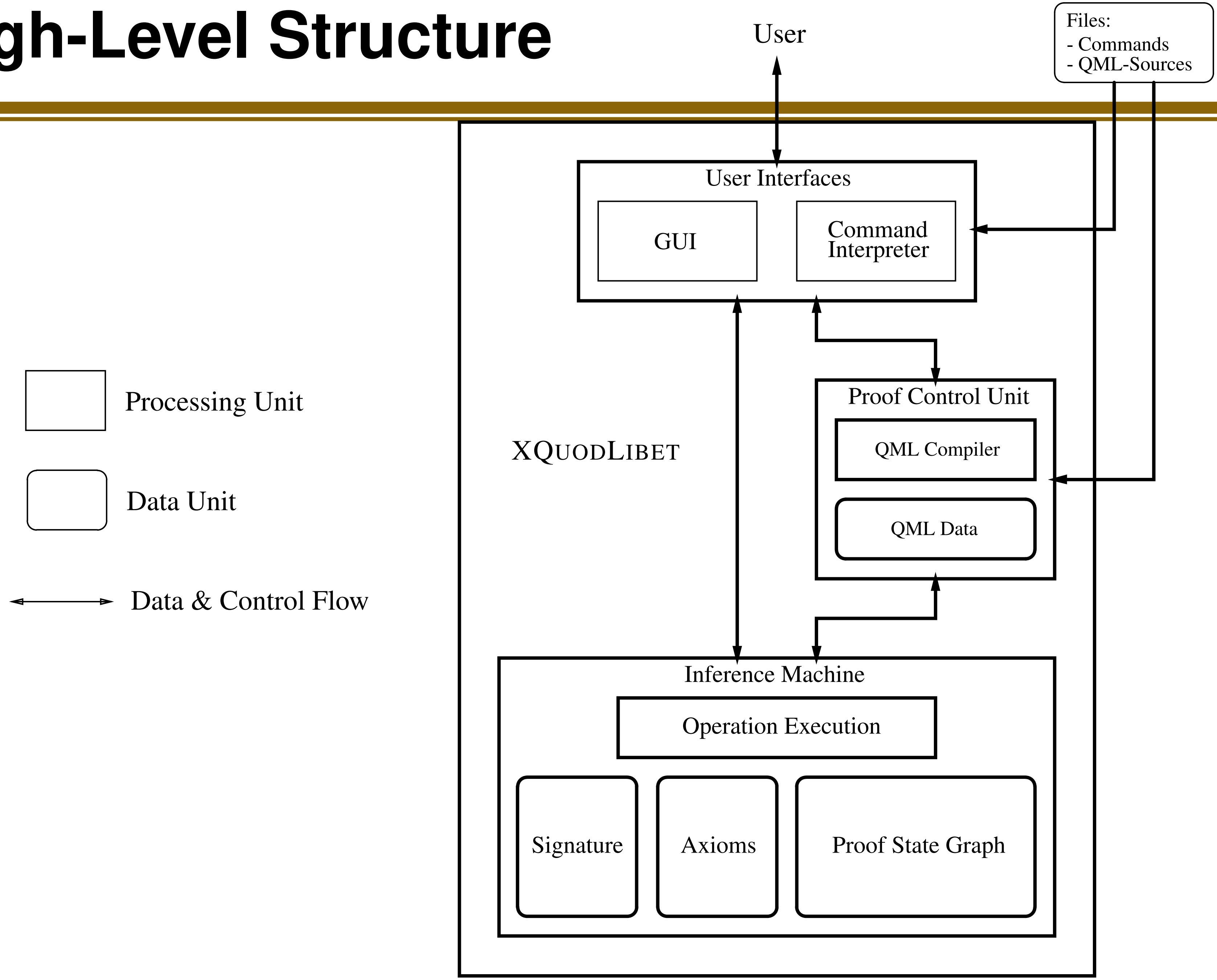
- User

Bernd Löchner	Zühlke Engin. GmbH

History and Future Plans

1990–1995	Requirements Analysis	Kühler, Wirth
1996	Specification	Kühler, Wirth
1996–2008	Overall Design and Coord.	Wirth
1997–2000	Implement. Vers. 1.1	Kühler, M.Sc.s
1998–2000	Termination Comp.	Kühler
1998–2000	Meta-language	Kühler
2003–2004	Implement. Vers. 1.2	Schmidt-Samoa, M.Sc.s
2004–2005	Markings + Presburger	Schmidt-Samoa
2005–2006	Proof Re-Use	Schmidt-Samoa
2005–2006	Implement. Vers. 1.3	Schmidt-Samoa, M.Sc.s
2005–2006	Case Study: LPO	Löchner, Schmidt-Samoa
2008–2009	Co-Inductive Data Types	Wirth
2009	Implement. Vers. 2.0	Wirth
2009–2010	Rippling, Program Synth.	Wirth, Edinburgh staff

High-Level Structure



Code

Module	Language	Size in KB
{Inference Machine + Command Interpreter}	COMMON LISP	60
SE/Visibility (MIL graphs)	COMMON LISP	532
QML Compiler	COMMON LISP	713
Heuristics	QUODLIBET ML	1839
GUI	TCL/TK	313

Selected Publications on QUODLIBET

∗ Claus-Peter Wirth (2008). *Shallow Confluence of Conditional Term Rewriting Systems.* Accepted by J. Symbolic Computation, 39 pp..

Tobias Schmidt-Samoa (2006). *Flexible Heuristic Control for Combining Automation and User-Interaction in Inductive Theorem Proving.* Ph.D. thesis, Univ. Kaiserslautern.

∗ Tobias Schmidt-Samoa (2006). *Flexible Heuristics for Simplification with Conditional Lemmas by Marking Formulas as Forbidden, Mandatory, Obligatory, and Generous.* J. Applied Non-Classical Logics **16(1–2)**, pp. 209–239.

Tobias Schmidt-Samoa (2006). *An Even Closer Integration of Linear Arithmetic into Inductive Theorem Proving.* Electronic Notes in Theoretical Computer Sci. **151**, pp. 3–20, Elsevier.

Serge Autexier, Christoph Benzmüller, Dominik Dietrich, Andreas Meier, Claus-Peter Wirth (2006). *A Generic Modular Data Structure for Proof Attempts Alternating on Ideas and Granularity.* 4^{th} MKM 2005, LNAI 3863, pp. 126–142, Springer.

Claus-Peter Wirth (2005). *History and Future of Implicit and Inductionless Induction: Beware the old jade and the zombie!.* In: Dieter Hutter, Werner Stephan (eds.). Mechanizing Mathematical Reasoning: Essays in Honor of Jörg Siekmann on the Occasion of His 60^{th} Birthday, LNAI 2605, pp. 192–203, Springer.

∗ Claus-Peter Wirth (2004). *Descente Infinie + Deduction.* Logic J. of the IGPL **12**, pp. 1–96, Oxford Univ. Press.

Jürgen Avenhaus, Ulrich Kühler, Tobias Schmidt-Samoa, Claus-Peter Wirth (2003). *How to Prove Inductive Theorems? QUODLIBET!.* 19^{th} CADE 2003, LNAI 2741, pp. 328–333, Springer.

Selected Publications on QUODLIBET (contd.)

Ulrich Kühler (2000). *A Tactic-Based Inductive Theorem Prover for Data Types with Partial Operations.* Ph.D. thesis, Infix, Akademische Verlagsgesellschaft Aka GmbH, Sankt Augustin, Berlin.

Claus-Peter Wirth (2000). *Full First-Order Sequent and Tableau Calculi With Preservation of Solutions and the Liberalized δ-Rule but Without Skolemization.* In: Ricardo Caferra, Gernot Salzer (eds.). Automated Deduction in Classical and Non-Classical Logics, LNAI 1761, pp. 283–298, Springer.

Claus-Peter Wirth (1999). *Full First-Order Free Variable Sequents and Tableaus in Implicit Induction.* 8^{th} TABLEAUX 1999, LNAI 1617, pp. 293–307, Springer.

Ulrich Kühler, Claus-Peter Wirth (1997). *Conditional Equational Specifications of Data Types with Partial Operations for Inductive Theorem Proving.* 8^{th} RTA 1997, LNCS 1232, pp. 38–52, Springer.

Claus-Peter Wirth (1997). *Positive/Negative-Conditional Equations: A Constructor-Based Framework for Specification and Inductive Theorem Proving.* Ph.D. thesis, 256 pp., Verlag Dr. Kovač, Hamburg.

Claus-Peter Wirth, Bernhard Gramlich (1994). *On Notions of Inductive Validity for First-Order Equational Clauses.* 12^{th} CADE 1994, LNAI 814, pp. 162–176, Springer.

$*$ Claus-Peter Wirth, Bernhard Gramlich (1994). *A Constructor-Based Approach for Positive/Negative-Conditional Equational Specifications.* J. Symbolic Computation **17**, pp. 51–90, Academic Press (Elsevier).