GOAL Extended:
Towards a Research Tool for Omega Automata and Temporal Logic

Ming-Hsien Tsai
Department of Information Management
National Taiwan University

Joint work with Yih-Kuen Tsay, Yu-Fang Chen, Wen-Chin Chan, and Chi-Jian Luo

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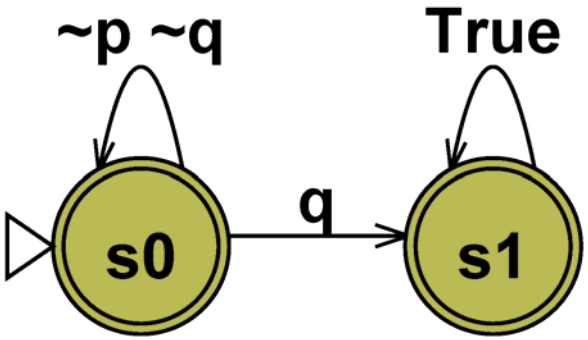
GOAL (**G**raphical Tool for **O**mega-**A**utomata and **L**ogics)

- GOAL is a graphical interactive tool, implemented in Java, for defining and manipulating
  - ω-automata, especially Büchi automata, and
  - temporal logic, specifically QPTL, formulae.
- It was first formally introduced in TACAS 2007.

Büchi Automata and QPTL

Büchi automata



Alphabets:

- **pq**
- **p~q**
- **~pq**
- **~p~q**

QPTL $\Box(p \rightarrow \diamondsuit q)$

An accepted word ~p~q, ~p~q, ~pq, ~p~q, p~q, ……

Motivation

- Teaching/Learning
  - Better understanding of the correspondence between ω-automata and temporal logic
- Supplementary Tool
  - A front end for model checking tools like SPIN
- Research
  - Comparing various complementation algorithms and translation algorithms
  - Checking correctness of a developing complementation or translation algorithm

Features of GOAL (partial listing)

- QPTL formulae
  - Checking satisfiability and validity
  - Translating via 9 algorithms (7 of them support past operators)
- Büchi automata
  - Testing inputs, emptiness, containment, etc
  - Taking closure, union, and intersection
  - Complementing via 4 algorithms
  - Simplifying by simulation and pruning fair sets

Features of GOAL (partial listing)

- Command-line mode
  - Most GOAL functions are accessible in the command-line mode
- Utility functions
  - Importing automata from external tools MoDeLLa and LTL2Buchi
  - Generating random QPTL formulae and Büchi automata
  - Taking statistical data such as the number of states

Research with GOAL

- Comparing translation algorithms
  1. $\sim(\Diamond p \rightarrow (\sim p \,\mathcal{U}\, (q \wedge \sim p \wedge \bigcirc(\sim p \,\mathcal{U}\, r))))$
  2. $\sim\Box(p \rightarrow (\Diamond\!\!\!-(r \wedge \ominus\Diamond\!\!\!-q)))$

No.	Tableau			Extended GPVW			GPVW+			Extended LTL2AUT			Extended LTL2AUT+			LTL2BA			PLTL2BA		
	st	tran	acc	st	tran	acc	st	tran	acc	st	tran	acc	st	tran	acc	st	tran	acc	st	tran	acc
1.	65	550	3	72	456	1	49	288	1	22	84	1	21	105	1	8	30	1	33	118	1
2.	49	396	1	13	55	1	-	-	-	9	23	1	8	17	1	-	-	-	15	38	1
1.	14	68	3	14	58	1	13	52	1	13	46	1	8	27	1	8	30	1	14	41	1
2.	10	26	1	7	21	1	-	-	-	5	10	1	5	10	1	-	-	-	10	23	1

Research with GOAL (cont'd)

- Comparing complementation algorithms

	States	Transitions	Time	Timeout
$\neg f$ to BA	1629	6906	$51.0s$	0
Safra	2461	11721	$175.7s$	6
Simplification+Safra	2077	9707	$22.1s + 114.8s$	5
WAPA	89196	4902278	$6346.3s$	51
Simplification+WAPA	8828	425248	$14.0s + 202.9s$	27
WAA	2920	27870	$3629.4s$	51
Simplification+WAA	1886	17740	$14.1s + 167.3s$	27
Piterman	1816	8314	$224.5s$	5
Simplification+Piterman	1531	6916	$23.4s + 442.4s$	3

Research with GOAL

- Checking correctness of a translation algorithm T against another proven algorithm T'
  1. Generate a set of formulae
  2. For each formula f
     a) Generate A_f and $A_{\sim f}$ by T'
     b) Generate B_f by T
     c) Test if both $A_{\sim f} \cap B_f$ and $A_f \cap \overline{B}_f$ are empty

DEMO

- Check the correctness of Extended LTL2AUT+
  - Let f = $\Box(p \rightarrow \diamondsuit q)$
  - Generate A_f and $A_{\sim f}$ by Tableau
  - Generate B_f by LTL2AUT+
  - Check if the following two automata are empty
    - $A_{\sim f} \cap B_f$
    - $A_f \cap B_f$
- Check the correctness of Extended LTL2AUT+ with shell scripts
- Compare translation algorithms with shell scripts

Summary

- Features of GOAL
  - Visualization of ω-automata
  - Many operations on Büchi automata and QPTL formulae
- Research with GOAL
  - Comparing translation and complementation algorithms
  - Checking correctness of developing translation algorithms
- Future of GOAL
  - More built-in algorithms
  - More automata types including alternating automata and games
  - More logics such as S1S

Thank You!

GOAL is available at
http://goal.im.ntu.edu.tw/

Suggestions are most welcome.