Commented Bibliography for the Lecture Course Tree Automata

Ralf Treinen

June 26, 2010

This document gives some pointers to the literature for the lecture course *Tree Automata* at the International Summer School on Rewriting 2010.

1 Tree Automata in General

Some references for original work on tree automata for the case of finite trees from the 60s are [Don65, Don70, TW65, TW68].

Today, the best text book to start on Tree Automata on finite trees is probably the freely available TATA book (Tree Automata and Applications) [CDG+07]. The project of maintaining a freely available book was started by the "schools" of Lille and Orsay (today Cachan) in France, who have both been pioneering in particular the various extensions of the tree automata model since the 80's. This book was designed to be extensible, that is authors who are competent to contribute a new chapter are welcome to join in. Since its first release in 1997, this project has seen the arrival of additional authors and chapters.

The classical reference on tree automata operating on infinite trees in [Rab69]. A good introduction to automata on infinite objects (words and trees) is [Tho90]. A (sketch of) a modern proof of the complementation theorem can be found in [Tho97].

2 Tree Automata and Logic

Both the TATA book [CDG+07] and Thomas' [Tho90] contain applications of the respective automata models to deciding logical theories. A more systematic study of the notion of *automatic structures* is Blumensath's master thesis [Blu99] and the pertaining paper [BG00]. My own lecture notes [Tre10] treats in general the question of decision procedures of complete logical theories, and among them automata based procedures (Chapters 10 and 11).

2.1 Application to Presburger Arithmetic

Presburger's original proof by quantifier elimination (not using automata) can be found in Chapter 7 of [Tre10]. The proof via encoding into WS1S and showing that the latter is automatic is due to [Büc60], a direct automata construction is discussed in [BC96].

2.2 Application to the theory of words

The undecidability of the extension to an unlimited binary concatenation operation is due to [Qui46], see also [Tre92].

2.3 Application to Skolem Arithmetic

I learned this proof from Damian Niwinski; I don't know a bibliographic reference for it.

2.4 Application to the Theory of a Monadic RPO

This is due to [NR00].

2.5 GTTs, Application to Multiple Congruence Relations

GTTs are due to [DTHL87, DTHL90], and are of course also covered in the TATA book. The application to multiple congruence relations isn't published yet.

2.6 Application to WS2S and S2S

This is a classic result due to Thatcher and Wright. See for instance the TATA book for the finite case only, and Wolfgang Thomas' [Tho90] for the infinite case. The presentation in my lecture notes [Tre10] follows closely the notion of automatic structures as defined by Blumensath and Grädel.

3 Extensions

Alternation and Bi-directionality in the non-equational case are treated in Chapter 7 of the TATA book [CDG+07]. See [Gou05] for the class $\mathcal{H}_1$ of alternating bi-directional automata. For alternation and bi-directionality in the equational case see Verma's PhD thesis [Ver03], and [VGL07].

For an overview obtained by the school of equational tree automata where state symbols are subject to equational axioms see Ohsaki's lecture notes [Ohs09].

Tree automata with constraints are in Chapter 4 of the TATA book, see there for pointers to the literature. However, TATA in the version of 2007 incorrectly states that the emptiness problem for (deterministic or non-deterministic) reduction automata is decidable. The undecidability proof for non-deterministic reduction automata is in [JRV08]. Undecidability of emptiness of automata with component-wise constraints has been shown in [Tre00, SAN+02]. Tree Automata with One Memory are defined and investigated in [CC05].

An introduction to tree automata for unranked trees is given in Chapter 8 of the TATA book [CDG+07].

References

[BC96] Alexandre Boudet and Hubert Comon. Diophantine equations, Presburger arithmetic and finite automata. In Hélène Kirchner, editor, *CAAP'96*, volume 1059 of *Lecture Notes in Computer Science*, Linköping, Sweden, April 1996. Springer-Verlag.

[BG00] Achim Blumensath and Erich Grädel. Automatic structures. In *15th Annual IEEE Symposium on Logic in Computer Science*, pages 51–62, Santa Barbara, CA, June 2000. IEEE Computer Society.

[Blu99] Achim Blumensath. Automatic structures. Master's thesis, Rheinisch-Westfälische Technische Hochschule Aachen, October 1999.

[Büc60] J. Richard Büchi. On a decision method in restricted second order arithmetic. In E. Nagel et. al., editor, *International Congr. on Logic, Methodology and Philosophy of Science*, pages 1–11. Stanford University Press, 1960.

[CC05] Hubert Comon and Véronique Cortier. Tree automata with one memory set constraints and cryptographic protocols. *Theoretical Computer Science*, 331(1):143–214, 2005.

[CDG$^+$07] Hubert Comon, Max Dauchet, Rémy Gilleron, Christof Löding, Florent Jacquemard, Denis Lugiez, Sophie Tison, and Marc Tommasi. *Tree Automata Techniques and Applications*. 2007. release October, 12th 2007.

[Don65] J. E. Doner. Decidability of the weak second-order theory of two successors. *Notices of the American Mathematical Society*, 12:365–468, March 1965.

[Don70] J. E. Doner. Tree acceptors and some of their applications. *Journal of Computer and System Sciences*, 4:406–451, 1970.

[DTHL87] Max Dauchet, Sophie Tison, Thierry Heuillard, and Pierre Lescanne. Decidability of the confluence of ground term rewriting systems. In *Proceedings of the Second Symposium on Logic in Computer Science*, pages 353–359, Ithaca, NY, USA, June 1987. The Computer Society of the IEEE.

[DTHL90] M. Dauchet, S. Tison, T. Heuillard, and P. Lescanne. Decidability of the confluence of finite ground term rewrite systems and of other related term rewrite systems. *Information and Computation*, 88(2):187–201, October 1990.

[Gou05] Jean Goubault-Larrecq. Deciding $\mathcal{H}_1$ by resolution. *Information Processing Letters*, 95(3):401–408, August 2005.

[JRV08] Florent Jacquemard, Michaël Rusinowitch, and Laurent Vigneron. Tree automata with equality constraints modulo equational theories. *Journal of Logic and Algebraic Programming*, 75(2):182–208, April 2008.

[NR00] Paliath Narendran and Michael Rusinowitch. The theory of a total unary rpo is decidable. In *Proceedings of the First International Conference on Computational Logic*, pages 660–672, London, UK, July 2000.

[Ohs09] Hitoshi Ohsaki. Introduction to tree language theory, July 2009. `http://staff.aist.go.jp/hitoshi.ohsaki/lecturenote.html`.

[Qui46] W. V. Quine. Concatenation as a basis for arithmetic. *Journal of Symbol Logic*, 11(4):105–114, 1946.

[Rab69] Michael O. Rabin. Decidability of second-order theories and automata on infinite trees. *Transactions of the American Mathematical Society*, 141:1–35, 1969.

[SAN+02] Zhendong Su, Alexander Aiken, Joachim Niehren, Tim Priesnitz, and Ralf Treinen. The first-order theory of subtyping constraints. In *POPL'02*, pages 203–216, Portland, OR, USA, January 2002. ACM.

[Tho90] Wolfgang Thomas. Automata on infinite objects. In Jan van Leeuwen, editor, *Handbook of Theoretical Computer Science*, volume B - Formal Models and Semantics, chapter 4, pages 133–191. Elsevier Science Publishers and The MIT Press, 1990.

[Tho97] Wolfgang Thomas. Languages, automata, and logic. In G. Rozenberg and A. Salomaa, editors, *Handbook of Formal Languages*, volume III, pages 389–455. Springer-Verlag, 1997.

[Tre92] Ralf Treinen. A new method for undecidability proofs of first order theories. *Journal of Symbolic Computation*, 14(5):437–457, November 1992.

[Tre00] Ralf Treinen. Predicate logic and tree automata with tests. In Jerzy Tiuryn, editor, *Foundations of Software Science and Computation Structures*, volume 1784 of *Lecture Notes in Computer Science*, pages 329–343, Berlin, Germany, March 2000. Springer-Verlag.

[Tre10] Ralf Treinen. Constraint solving and decision problems of first-order theories of concrete domains, January 2010. `http://www.pps.jussieu.fr/~treinen/publi/constraints.ps.gz`.

[TW65] J. W. Thatcher and J. B. Wright. Generalized finite automata. *Notices of the American Mathematical Society*, 820, 1965.

[TW68] J. W. Thatcher and J. B. Wright. Generalized finite automata with an application to the decision problem of second-order logic. *Mathematical System Theory*, 2:57–82, 1968.

[Ver03] Kumar Neeraj Verma. *Automates d'arbres bidirectionnels modulo téories équationnelles*. PhD thesis, ENS de Cachan, September 2003.

[VGL07] Kumar Neeraj Verma and Jean Goubault-Larrecq. Alternating two-way AC-tree automata. *Information and Computation*, 205(6):817–869, 2007.