

Advances and Applications of Automata on Words and Trees

— Executive Summary —

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The aim of the seminar was to discuss and systematize the recent fast progress in automata theory and to identify important directions for future research. For this, the seminar brought together more than 40 researchers from automata theory and related fields of applications. We had 19 talks of 30 minutes and 5 one-hour lectures leaving ample room for discussions. In the following we describe the topics in more detail.

1 Monday

Thomas Wilke gave the opening lecture on functional programs for regular expression matching. He demonstrated how it is possible to develop a non-trivial algorithm online during a talk (by typing Haskell). Bill Wadge talked about degree operations and presented the game/automata characterizations of the Wadge degrees, of the degree multiplication operation of Steele and van Wesepe, and reported on the search for degree exponentiation. Friedrich Otto gave a presentation on non-forgetting deterministic restarting automata that are monotone. He presented a hierarchy of language classes that are characterized by various types of non-forgetting, deterministic, and monotone restarting automata, which ranges from the deterministic context-free languages to the so-called left-to-right regular languages.

The space of one-sided infinite words plays a crucial role in several parts of Theoretical Computer Science. For several purposes, topologies other than the one of the Cantor space are useful, e.g., for studying fragments of first-order logic over infinite words or for a topological characterization of random infinite words. For this end, Ludwig Staiger talked about topologies that refine the Cantor topology.

Jacques Sakarovitch showed that the enumerating series brings a structuring vision to abstract numeration systems. The talk showed that it is decidable whether an N-rational series corresponds to a rational abstract numeration system. Christian Reitwießner talked about Boolean grammars, which are an extension of context-free grammars. In contrast to context-free grammars, they can generate quite complicated non-regular languages over a single-letter alphabet. The talk discussed the parsability of Boolean grammars and showed that they can be efficiently parsed. In his talk, Jacques Duparc explained that the Wadge hierarchy of omega-regular tree languages is huge. He defined a weighted monadic second order logic for unranked trees and the concept of weighted unranked tree automata, and investigated the expressive power of these two concepts.

2 Tuesday

The second lecture of the seminar was presented by Thomas Colcombet and it surveyed important results concerning distance automata and their extensions: Krob's undecidability result, Hashiguchi's result of decidability of the limitedness problem, and the decidability of the star-height problem due to Hashiguchi.

Volker Diekert and Manfred Kufleitner gave a series of talks on small fragments of first-order logic over finite and infinite words. They showed how to combine algebraic and topological properties in order to generalize decidability results to infinite words. Markus Lohrey talked about isomorphism problems on automatic structures and showed several hardness results for the isomorphism problem for transitive relations.

There are developments in automata theory that borrow important ideas from game theory. For this end, Veronique Bruyere gave a talk on equilibria in quantitative reachability games. The talk considered turn-based quantitative multiplayer non zero-sum games played on finite graphs with reachability objectives, and it proved the existence of finite-memory Nash equilibria in multiplayer games. Zoltan Esik talked about axiomatizing regular tree languages and presented complete axiomatizations of regular languages of ranked trees. Christian Choffrut gave a talk on extensions of the theorem by Eilenberg, Elgot, and Shepherdson.

3 Wednesday

The Wednesday's lecture was given by Howard Straubing who talked about algebras and logics for unranked forests.

One of the fundamental topics in mathematics is the search for relations between local and global regularities. Juhani Karhumaeki analyzed this phenomena in connection with infinite words. Local regularity here means that the word possesses everywhere some local (finitely describable) regularity condition, such as some type of local periodicity, while the global regularity means that the word is periodic (or ultimately periodic).

Victor Selivanov talked about the fine hierarchy of omega-regular k -partitions. The talk developed the theory of ω -regular k -partitions that extends the theory around the Wagner hierarchy of regular ω -languages. In particular, it characterized the structure of Wadge degrees of ω -regular k -partitions, proved the decidability of any level of the corresponding hierarchy, established coincidence of the reducibilities by continuous functions and by functions computed by finite automata on the ω -regular k -partitions, and showed the undecidability of the first-order theory of the structure of Wadge degrees of regular k -partitions for each $k \geq 3$.

Bahareh Afshari talked about new results on the decidability of the mu-calculus alternation hierarchy. The starting point was the open question of whether a given formula is equivalent to a formula with a lower alternation depth. In the talk we learned about partial results for the class of Δ_2 formulae.

4 Thursday

The seminar started with a lecture by Thomas Schwentick about automata for data words. The talk gave a basic introduction into automata models that have been proposed for data strings and data trees, that is, strings and trees enhanced by data values. The emphasis was on expressiveness and complexity.

Paul Gastin talked about weighted automata with pebbles and weighted FO logic with transitive closures. Here a new classes of weighted automata on words was introduced. Equipped with pebbles and a two-way mechanism, they go beyond the class of recognizable formal power series, but capture a weighted version of first-order logic with bounded transitive closure. The talk also discussed new logical characterizations of the recognizable series.

Manfred Droste gave a talk on weighted logics for unranked tree automata, where he defined a weighted monadic second order logic for unranked trees and the concept of weighted unranked tree automata. It was shown that the weighted tree automata and a syntactically restricted weighted MSO-logic have the same expressive power in case the semiring is commutative or in case we deal only with ranked trees, but, surprisingly, not in general. This demonstrated a crucial difference between the theories of ranked trees and unranked trees in the weighted case. In the last talk of this session, Julian Bradfield explained us what spiders and finite automata have in common.

Damian Niwinski explained the separation problem in the index hierarchy and showed that a certain pair of disjoint co-Buchi recognizable sets is complete for all disjoint pairs of co-analytic sets. The proof involved a construction of a “dichotomic” automaton.

Pierre McKenzie made an excursion to computational complexity and explained us DAG evaluation and the red-blue problem. Alexander Rabinovich talked about decidable expansions of labeled linear orderings, where he proved that if certain monadic second-order theories are decidable, then they have non-trivial expansions that are still decidable.

5 Friday

The Friday's lecture was given by Luc Segoufin, who talked about models of tree walking automata and transitive logic on trees. Ludmila Yartseva gave a talk on definability in the structures with subword order, where she developed a theory of first-order definability in the subword partial order in parallel with similar theories for the h -quasiorder of finite k -labeled forests and for the infix order.

Alexander Okhotin gave a survey on language equations and told us the exciting story of computational completeness. His talk described the research path from encountering the first undecidable properties of language equations in 1998 to establishing the computational completeness of their ultimately simple case: systems over a one-letter alphabet using concatenation only in 2008.

Christof Loeding talked about the nondeterministic parity index problem, which consists in finding for a given regular language of infinite trees the minimal range of priorities needed by a nondeterministic parity automaton accepting the language. The talk presented a recent approach to tackle this problem. Here the main idea is to translate the problem into a limitedness problem for distance parity automata.

6 Conclusions

The talks in this seminar ranged over a broad assortment of subjects with the underlying theme of automata on words and trees. It was a very fruitful seminar and has hopefully initiated new directions in research. We look forward to similar meetings in the future!