Abstract of PhD Thesis

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Abstract

In 1977, Pnueli introduced *Linear Temporal Logic* (*LTL* for short) as a propositional logic with two future temporal connectives *"next"* and *"until"*, and suggested it as a suitable tool for reasoning about the executions of programs. This opened the road for the application of temporal logic in program correctness, since after that *LTL* has been used to a number of practical applications (especially industrial) in model checking. The automata-theoretic approach is one of the main ways to develop model checking theories that was originally suggested by Vardi and Wolper in 1986. Its core is that each *LTL* formula φ can be represented by a nondeterministic Büchi automaton. Apart from the notable applications, results on the expressive power of *LTL* are considered fundamental in the theory of computer science. More precisely, *LTL*-definable languages are known to coincide with languages definable by first-order (*FO* for short) logic, star-free languages, aperiodic languages and counter-free languages. This result holds for finitary languages, i.e., languages over finite words as well as for infinitary languages (over infinite words). These different characterizations of the same class of languages were proved by several authors; the results for infinite words required more sophisticated techniques than the ones for finite words.

In this doctoral thesis we study the concepts of weighted *LTL*, weighted *FO* logic, ω-star-free series and weighted counter-free Büchi automata. Our motivation lies in the last years' increasing interest in lifting fundamental results from classical to quantitative models. This is driven by the need to develop model checking tools incorporating quantitative features. This need, but also the deep theoretical interest, led several researchers to consider and investigate quantitative versions of logics.

The contents of the thesis are as follows. Chapter 1 contains the introduc-

tion, and Chapter 2 the preliminaries. In Chapter 3, we introduce the notions of weighted *LTL*, weighted *FO* logic, ω-star-free expressions and weighted counter-free Büchi automata. The underlying structure is the the max-plus semiring $\mathbb{R}_{\max} = (\mathbb{R}_+ \cup \{-\infty\}, \max, +, -\infty, 0)$. We interpret these objects over infinite words. In order to ensure the existence of infinite sums we use the method of discounting. In our first main result, we establish the expressive equivalence of formulas in a fragment of the weighted *LTL*, of sentences in a fragment of the weighted *FO* logic, ω-star-free expressions and a subclass of weighted counter-free Büchi automata. Though, we do not state it explicitly, this result can easily be stated for finitary series, i.e., series over finite words, as well.

In Chapter 4, we define the concept of weighted generalized Büchi automata with discounting and ε-transitions, and prove that they are equivalent to weighted Büchi automata with discounting; models which have been studied in the literature. In our second main result, we present an effective translation, of a syntactic fragment of our weighted *LTL* to weighted generalized Büchi automata with ε-transitions.

In the third main part of the thesis, in Chapter 5, we study a weighted *LTL*, a weighted *FO* logic, ω-star-free series and weighted counter-free Büchi automata over additively idempotent and zero-divisor free totally commutative complete semirings. Intuitively, *complete* means that our semirings permit infinite sums and products. In the setup of these semirings, we establish the last main result. More precisely, we show that the class of infinitary series definable by formulas in a fragment of the weighted *LTL* coincide with the class of infinitary series definable by sentences in a fragment of the weighted *FO* logic, with the class of ω-star-free series and with the class of almost simple ω-counter-free series (a subclass of the class of series accepted by weighted counter-free Büchi automata).

Finally in the conclusion, in Chapter 6, interesting problems for future research are addressed. For instance, the investigation of the complexity of our constructions, and the establishment of our equivalence result of Chapter 5, in the setup of algebraic structures which are not semirings any more. Both of them are of great importance for practical applications

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