Automata and Logic on Infinite Objects

Automata on infinite words (or infinite trees) play a key role in the design of algorithms for verification and synthesis of reactive systems. Reactive systems are systems (and programs) that maintain an ongoing interaction with their environment, e.g. operating systems, interactive games, robotic swarms, etc. The computations in such systems can be described as infinite words or trees describing the state of the system along the time line.
specification of such systems can be formally described using temporal logics, logics which reason on the evolution of events over time. The verification problem is concerned with answering whether the system satisfies its formal specification. The synthesis problem is concerned with devising automatic methods to construct a system that adheres to its formal specification. The verification and synthesis questions can be reduced to questions on automata on infinite words or trees.

The theory of automata on infinite words (a.k.a. omega-automata) is more involved than that on finite words, and many fundamental questions, such as minimization, are still open. In this course we will get familiarized with the various types of omega-automata. We will study the differences in expressive power and succinctness. We will review algorithms for verification and synthesis, following algorithms for basic operations, such as Boolean closures and emptiness. We will track the intricacies that make omega-automata more involved, as well as the beauty and elegance of the hierarchy of regular omega-languages they induce. We will get familiar with linear and branching temporal logics, and the different and commonalities in their expressive power.

**Detailed Syllabus**

- Omega-regular properties (along the Manna-Pnueli Hierarchy)
- Büchi automata, closure properties
- The power of non-deterministic Büchi automata
- Other types of omega-automata: co-Büchi, Rabin, Streett
- Omega-regular expressions, S1S and Büchi’s theorem
- Alternating automata, the Miyano-Hayashi construction
- Muller and Parity automata, the latest appearance record construction
- Determinization and Complementation of Büchi Automata
- The Wagner hierarchy

If time permits, one or few of the following:

- Verification and synthesis of reactive systems
- Branching temporal logics: CTL, CTL*
- The differences and commonalities between LTL, ACTL, CTL, CTL*.  
- 2-player infinite games
- Automata over trees

- [70%] Homework assignments (4-6), done individually, prepared in LaTeX.
- [10%] Active participation, i.e. contributing to the class academic discussion.
- [20%] Final quiz, the quiz includes theoretical questions on the definitions, theorems, algorithms and proofs taught in the course.
- A passing grade in the course requires a passing grade in both the average of quizzes and the average of homework assignments.
Books:

Survey papers:
- Languages, Automata and Logic by Wolfgang Thomas, 1996.
- Infinite games played on finite graphs by Robert McNaughton, 1993.
- Infinite Games Lecture Notes by Martin Zimmermann, Felix Klein, and Alexander Weinert, 2016.