CSE681 **Formal Languages I** **Spring 2012**

Course Format

The course will have a standard lecture/homework format, with letter grading. While a seminar fosters reading in a field and the free exploration of stimulating ideas, an advanced theory course covers research fundamentals and assures proficiency with important problem-solving tools and methods.

Coursework will be graded on a total-points system. This will include a take-home final worth 30–35% of the points. It may also include a term paper and one-session presentation—in particular, this could constitute a Master's Project in a 6xx course.

Course Material

Formal languages as a subject predates computational complexity theory. However, formal languages remain the vertebrae for the "animals" in the Complexity Zoo, especially for classes below P and NP where the frontiers for lower bounds lie. That is to say, important formal languages are *complete* for many of these classes. For example:

- The most complex *regular languages* are complete for the logarithmic time parallel complexity class NC^1.
- Evaluation in formal propositional logic is also complete for NC^1.
- Logarithmic space L and its non-deterministic cousin NL are sandwiched between NC^1 and LOGCFL, which represents the complexity of context-free languages. CFL's are still all solvable in polynomial time.
- The formal multiplication relation is complete for a subclass of NC^1 called TC^0 for poly-size constant-depth threshold circuits, which may best model human brains.
- Arithmetic modulo some composite number yields the subclass ACC^0 right on the frontier of lower bounds.
- First-order formal arithmetic (on small numbers that index bits of strings) characterizes AC^0, which stands for poly-size constant-depth circuits and is a proper subclass of ACC^0.

That said, the course will take the "modern" angle of emphasizing the *classes* rather than the formal languages, and as such complements CSE696, which mainly covers classes above P. The text will comprise the following standard materials:

1. Three book chapters co-authored by me with Eric Allender (Rutgers) and Michael Loui (UIUC) for the *CRC Handbook of Algorithms and Theoretical Computer Science*, available on my publications page.
2. Lecture Notes by Alexis Maciel and David Mix Barrington on *descriptive complexity*, which is the term for describing the above classes by formal systems of logic. These are linked on my course webpage, `http://www.cse.buffalo.edu/~regan/cse681/`.
3. Articles on the weblog *Gödel's Lost Letter and P=NP* (GLL) and supplementary materials from survey papers.

In 2010 I covered *communication complexity* in the last month of the course, using lecture notes by Rocco Servedio at Columbia. This time my intent is to do more with logics and the formal status of lower bounds. This is influenced by results in late 2010 obtaining new lower bounds against ACC^0. An example showing this emphasis that could also be the subject of a student presentation is the conversion of knot diagrams into a formal language in my post today for GLL (which is often considered one of the three top theoretical computer science blogs, not a usual course weblog):

`http://rjlipton.wordpress.com/2012/01/13/what-makes-a-knot-knotty/`

However, I will take your interests into account when delineating the later lectures.

Prerequisites: CSE596 **or** CSE theory area graduate seminar **or** CSE531 plus complexity basics if needed (if NP-completeness was covered then basically fine) **or** permission of instructor, possibly rogering a good undergraduate course.