Semester Report Manuel Bodirsky

Supervisor:	Prof. Dr. Hans Jürgen Prömel
Field of Research:	Algorithmic Graph Theory
Topics:	(Random) Outerplanar Graphs;
	Computing Limit Densities;
	Computing Tree-orientations of Posets.
PhD Student	at the program since april 2001

Fields of Research and Results

I worked on several topics. The first is a problem related to the tree description formalisms that I studied in my diploma thesis. Already in Saarbrücken we found that a published algorithm for so-called *Pure Dominance Constraints* is incomplete [7]. The last months in Berlin I saw that a subproblem thereof nicely tanslates into a graph theoretic problem, namely the question whether a partial order can be refined into a tree, such that some given pairs of elements remain incomparable. Martin Kutz (CGC since June 2001) then found an interesting and very efficient algorithm for this problem, which is also related to some work of Rote at al. [10].

Another subject is the computation of the limit density of regular languages. It is a well-known fact that for a given first order formula ϕ without function symbols, the limit of the fraction of structures of size n satisfying ϕ for growing n is either zero or one. It is less well-known that the property of a formula to be true *almost always* is PSPACE-hard. In [5] we showed that for regular languages represented by finite deterministic automata it is in coNP to check whether the language is *dense* in the above sense. Previously it was only known, that the densities of regular languages have finitely many rational accumulation points [1]. The problem whether there is a polynomial time algorithm remains open, but we can show that it is equivalent to the following simply stated decision problem: Given a sequence of sequences of integers $(a_i)_{i=1}^n$, is the sum $\sum_{i=1}^n a_i^\omega = (0)^\omega$, i.e. do these sequences, repeated infinitely often, equal zero if we add them componentwise. We can also show that if the regular language is represented by a nondeterministic finite automaton, the problem becomes NP-hard.

Finally, I'm very much interested in *outerplanar* graphs, an important subclass of planar graphs. It is unknown whether a *planar* graph can be generated uniformly at random in polynomial time. A Markov-chain method

has been proposed to do this at least approximatively, but it is unknown whether the Markov-process is rapidly mixing [8]. There is some progress on calculating the number of planar graphs, but the lower bound of $n!26.1^{n+o(n)}$ and upper bound of $n!37.3^{n+o(n)}$ still leave some gap [12]. So I would like to attack these questions at least for outerplanar graphs, i.e. the graphs that can be embedded in the plane such that all vertices lie on the outer face, or equivalently, the graphs without a K_4 and a $K_{2,3}$ minor. These graphs have a much simpler structure [13], but we still have the problem that an outerplanar graph may have several planar embeddings. Related to this, I'm interested in the conjecture that every planar graph can be edge-partitioned into two outerplanar graphs [6, 11]. Independent of the conjecture being true or not, one could ask the new question whether such a partition can be found in polynomial time (cf. edge partitions of planar graphs into three forrests can easily be found).

Activities

- The 12th International Conference on Rewriting Techniques and Applications (RTA) in Utrecht, 22.-24.5.2001, contributing [2].
- The 16th Annual IEEE Symposium on Logic in Computer Science (LICS), Boston, 16.-19.6.2001, with a short talk about [5].
- Colloquia of the Graduate Program.
- CGC-Workshop in Ascona, 13.-15.5.2001 (talking about *Pure Dominance Constraints*).
- Blockcourse *Graph Theory and Connectivity* by Andràs Frank.
- Lecture *Graphen und Algorithmen II* by Stefan Hougardy.
- Colloquia of the Department Algorithms and Complexity at Humboldt University.
- The 27th Berliner Algorithmentag, and the Workshop on Combinatorics and Random Structures, Humboldt-Universitt zu Berlin, 5-7. July 2001.

Preview

Very much looking forward to

- European Summer School for Logic, Language and Information, August 10–24, Helsinki; and the ESSLLI 2001 Student Session [5].
- The Fall School Discrete Geometry: Triangulations from various points of view, October 4–6, Berlin.
- Block courses *Randomized Algorithms* by Emo Welzl, and *Topological Methods in Combinatorics and Geometry* by Jiri Matousek, both in Zürich.

Literatur

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[2] M. Bodirsky, K. Erk, A. Koller and J. Niehren. *Beta Reduction Constraints*. In International Conference on Rewriting Techniques and Applications. Lecture Notes in Computer Science, Utrecht, May 22–24, 2001. Available at `http://www.informatik.hu-berlin.de/~bodirsky/publications.html`.

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[6] G. Chartrand, D.P. Geller, and S. Hedetniemi, *Graphs with forbidden subgraphs*, Journal Combinatorial Theory B 10 (1971), 12-41.

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[9] Etienne Grandjean, *Complexity of the First-Order Theory of Almost All Finite Structures*, Information and Control 57 (1983), 180–204.

[10] Paul Hilfinger, Eugene L. Lawler and Günter Rote. *Flattening a Rooted Tree*, Applied Geometry and Discrete Mathematics 4 (1991), 335–340.

[11] Kiran S. Kedlaya, *Outerplanar Partitions of Planar Graphs*, Journal of Combinatorial Theory Series B 67 (1996), 238-248.

[12] Deryk Osthus, Hans Jürgen Prömel and Anusch Taraz, *On random planar graphs, the number of planar graphs and their triangulations*, submitted.

[13] Josef Leydold and Peter F. Stadler, *Minimal Cyle Bases of Outerplanar Graphs*, submitted.