Esprit Working Group 21726, "RAND2"

Report on the Edinburgh Site, 1998–99

Overview of recent developments

- *Contention Resolution.* We have continued to study the stability of backoff protocols in multiple-access channels such as the Ethernet channel and optical channels. Reference [1] shows that the Binary Exponential Backoff protocol, on which Ethernet is based, is stable (in the presence of queues) for relatively high arrival rates. Most of our research has focussed on discovering the stability threshold of backoff protocols in the absence of queues. We have improved the current bound, showing that no backoff protocol can achieve throughput .53.

- *The computational complexity of counting or sampling unlabelled structures.* Aside from a small amount of existing work, this line of enquiry is largely new. Reference [10] considers unlabelled sampling in the context of the Pólya theory, and demonstrates that a certain natural Markov chain simulation approach will not provide efficient solutions in all circumstances. Reference [11] provides an early result of a different nature: that *exactly* counting unlabelled subtrees of a tree is #P-complete and hence almost certainly computationally intractable. A number of interesting questions are raised by this, include the status of approximate counting (see next paragraph).

- *Non-approximability results for counting.* As mentioned in last year's report, this is a poorly developed area, though some non-trivial results are beginning to emerge. Given the paucity of strong negative results, we are engaged in a programme of classifying counting problems using a notion of "approximation-preserving reducibility." Some interesting structure appears to be emerging.

- *Incremental improvements to MCMC analysis.* Definite progress has been made in the continuing search for new and improved MCMC (Markov chain Monte Carlo) algorithms for counting problems. Reference [6] shows how to extend the range of applicability of path-coupling analysis by avoiding the need to consider always worst-case situations.

Personnel

Mark Jerrum, Jung-Bae Son (postgraduate student, from 4th October, 1999), Leslie Goldberg (Department of Computer Science, University of Warwick). Mary Cryan (postgraduate student, Department of Computer Science, University of Warwick, until September 1999). Steven Kelk (postgraduate student, Department of Computer Science, University of Warwick, from September 1999).

Publications

[1] H. Al-Ammal, L.A. Goldberg and P. MacKenzie, Binary Exponential Backoff is stable for high arrival rates, Research Report 359, Department of Computer Science, University of Warwick (July 1999).

[2] Russ Bubley, Martin Dyer, Catherine Greenhill and Mark Jerrum, On approximately counting colourings of small degree graphs, Preprint, October 1998. Submitted to *SIAM Journal on Computing.*

[3] M. Cryan, L.A. Goldberg and P.W. Goldberg, Evolutionary Trees can be Learned in Polynomial Time in the Two-State General Markov Model, *Proceedings of the Symposium on Foundations of Computer Science (IEEE)* **39** (1998) 436–445.

[4] M. Cryan, L.A. Goldberg and C.A. Phillips, Approximation Algorithms for the Fixed-Topology Phylogenetic Number Problem, *Algorithmica* **25** (1999) 311–329.

[5] Martin Dyer, Alan Frieze and Mark Jerrum, On counting independent sets in sparse graphs, *Internal Report ECS-LFCS-98-391*, Department of Computer Science, University of Edinburgh, July 1998. (To appear in *Proceedings of the 40th IEEE Symposium on Foundations of Computer Science* (FOCS '99), October 1999.)

[6] Martin Dyer, Leslie Ann Goldberg, Catherine Greenhill, Mark Jerrum and Michael Mitzenmacher, An extension of path coupling and its application to the Glauber dynamics for graph colourings. To appear in *Proceedings of the 11th Annual ACM-SIAM Symposium on Discrete Algorithms* (SODA'00).

[7] L.A. Goldberg, Randomly Sampling Unlabelled Structures, Research Report 356, Department of Computer Science, University of Warwick (April 1999).

[8] L.A. Goldberg, P.W. Goldberg, M. Paterson, P. Pevzner, S.C. Sahinalp and E. Sweedyk, The Complexity of Gene Placement, *Proceedings of the ACM-SIAM Symposium on Discrete Algorithms* **10** (1999) 386–395.

[9] L.A. Goldberg, W.E. Hart and D.B. Wilson, Analysis of a Simple Learning Algorithm: Learning Foraging Thresholds for Lizards, *Journal of Theoretical Biology,* **197** (1999) 361–369.

[10] Leslie Ann Goldberg and Mark Jerrum, The "Burnside process" converges slowly. In: Randomization and Approximation Techniques in Computer Science (M. Luby, J. Rolim and M. J. Serna, eds.), *Springer-Verlag LNCS* **1518**, 1998, 331–345.

[11] Leslie Ann Goldberg and Mark Jerrum, Counting unlabelled subtrees of a tree is #P-complete. (In preparation.)

[12] L.A. Goldberg and P.D. MacKenzie, Analysis of Practical Backoff Protocols for Contention Resolution with Multiple Servers, *Journal of Computer and Systems Sciences*, **58** (1999) 232–258.

[13] L.A. Goldberg, Y. Matias and S. Rao, An Optical Simulation of Shared Memory, *SIAM Journal on Computing* **28(5)** (1999) 1829–1847.

[14] Yoram Hirshfeld and Mark Jerrum, Bisimulation equivalence is decidable for normed Process Algebra (Extended abstract), *Proceedings of 26th International Colloquium on Automata Languages and Programming* (ICALP '99), Springer-Verlag, 1999.

Research Visits

- Visit by Mark Jerrum to the Computer Science Department, Warwick University, December 1998.
- One-week visit by Mark Jerrum to the School of Computer Studies, Leeds University, April 1999.
- One-week visit by Leslie Goldberg to the School of Computer Studies, Leeds University, May 1999.
- One-week visit by Leslie Goldberg to the School of Computer Science, Edinburgh University, May 1999.
- Two-week visit by Leslie Goldberg to the Department of Computer and Information Science, University of Pennsylvania, August 1999.

Conferences/workshops attended

- *39th Symposium on Foundations of Computer Science (FOCS39),* Palo Alto, CA, USA, November 1998. Mary Cryan (contributed talk: "Evolutionary trees can be learned in polynomial time in the two-state general Markov model").
- *EPSRC/LMS Workshop on Phase Transition Phenomena in Combinatorial Problems,* Liverpool, January 1999. Leslie Goldberg (invited talk: "Randomly sampling unlabelled structures").
- One Day Meeting in Combinatorics, University College London, February 1999. Mark Jerrum (invited talk: "How (not) to sample random unlabelled structures").
- RAND2 Meeting, Gif-sur-Yvette, May 1999. Mark Jerrum (contributed talk, "Independent sets in bounded-degree graphs").
- France-Berkeley workshop *Phase transitions and complexity*, Orsay, May 1999. Mark Jerrum (participant).
- *ALCOM Workshop*, Barcelona, June 1999. Leslie Goldberg (participant).

- *Liverpool Algorithms Day,* Liverpool, June 1999. Leslie Goldberg (participant).
- *Schloß Dagstuhl seminar on Parallel and Distributed Algorithms,* July 1999. Leslie Goldberg (invited talk: Stability of backoff protocols").
- 17th *British Combinatorics Colloquium*, Canterbury, July 1999. Mark Jerrum (contributed talk: "Coupling random walks on vertex- and edge-colourings of graphs").
- FoCM'99 (Foundations of Computational Mathematics), Oxford, July 1999. Mark Jerrum (invited talk: "An introduction to the computational complexity of measurement").
- Jyväskylä Summer School, Finland, August 1999. Mark Jerrum (series of ten lectures: "The Markov chain Monte Carlo method: a rigorous approach").
- Conference on *NP-hardness and Phase Transitions*, Trieste, September 1999. Mark Jerrum (invited talk: "The independent set (hard-core gas) model: phase transition and intractability").
- RAND2 Meeting, Oxford, September 1999. Leslie Ann Goldberg (contributed talk: "Learning evolutionary trees"); Mark Jerrum (contributed talk: "Counting unlabelled subtrees of a tree is #P-complete").