CSCI 688-02

Scale-Free Networks

Course Syllabus—Fall 2009

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PREREQUISITES: Csci 141, Csci 241, and Math 323 (high-level programming language, elementary data structures and rudimentary knowledge of optimization) or their equivalent.

DESCRIPTION: In the late 1990s a number of researchers noticed that networks in biology, sociology, and telecommunications exhibited similar characteristics unlike standard random networks. In particular, researchers found that the cummulative degree distributions of these graphs followed a power law rather than a binomial distribution and that their clustering coefficients tended to a nonzero constant as the number of nodes, n, became large rather than O(1/n). Moreover, these networks shared an important property with traditional random graphs—as n becomes large the average shortest path length scaled with log n. This latter property has been coined the small-world property. When taken together these three properties—small-world, power law, and constant clustering coefficient—describe what are now most commonly referred to as scale-free networks.

TOPIC OUTLINE: The reading material from the books Linked and Complexity is to be discussed in class. You will be given questions for each chapter and will be expected to actively participate in classroom discussion. Coincident with these chapters we will cover basic graph theory and portions of a *SIAM Review* article. There will be group research projects in lieu of a final exam.

week 1: Ch. 1-3 of Linked; 1-3,1-4,1-5 of Chartrand
week 2: Ch. 4-6 of Linked; 1-6,2-1,2-2 of Chartrand
week 3: Ch. 7-9 of Linked; 2-3,2-4 of Chartrand
week 4: Ch. 10-12 of Linked; 3-1,3-2 of Chartrand
week 5: Ch. 13-16 of Linked; Sec. 1-2 Newman; Ch. 1 Complexity
week 6: Sec. 3-4 Newman; Ch. 2,3 Complexity
week 7: Sec. 5-6 Newman; Ch. 15,16,17 Complexity
week 8: Sec. 7-8 Newman; Ch. 18,19 Complexity
Exam
week 9: Paper by LATDW (2005).
week 10: Paper by Willinger, Doyle and Li (2004).
week 11: Executive Summary by students of current papers
week 12: Executive Summary by students of current papers
week 13: Group Project meetings with RKK
week 14: Project presentations.

REFERENCES:

1. Barabasi, A-L., Linked: The New Science of Networks, Perseus Publishing, Cambridge, Massahusetts, 2002.
2. Mitchell, M. Complexity: A Guided Tour, Oxford University Press, 2009.
3. Newman, M.E.J., "The Structure and Function of Complex Networks," (2003) *SIAM Review*, Vol. 15, No. 2, pp. 167-256.
4. Chartrand, G., Introductory Graph Theory, Dover Publications Inc., New York, 1977.
5. Bollobas, B., Random Graphs, Academic Press, New York, 1985.
6. Li, L., D. Alderson, R. Tanaka, J.C. Doyle and W. Willinger, "Towards a Theory of Scale-Free Graphs: Definition, Properties, and Implications (Extended Version)", Technical Report CIT-CDS-04-006, Cal Tech, 2005. (arXiv:cond-mat/0501169 v1 9 Jan 2005)
7. Willinger, W., J.C. Doyle, and L. Li, "More Normal than Normal Scaling Distributions and Complex Systems," *Proceedings of the 2004 Winter Simulation Conference* pp. 130-141.
8. Tangmunarunkit, H., R. Govindan, S. Jamin, S. Shenker, and W. Willinger, "Network Topology Generators: Degree Based vs. Structural," *SIGCOMM '02*, August 19-23, 2002, Pittsburgh, PA.
9. Atay, F., T. Bihikoglu, and J. Jost, "Synchronization of Networks with Prescribed Degree Distribution," Working Paper. (arXiv:nlin.AO/0407024 v2 29 May 2005)
10. Csermely, P. Weak Links: Stabilizers of Complex Systems from Proteins to Social Networks, Springer (The Frontiers Collection) 2006.
11. Brandes, U. and T. Erlebach (editors), Network Analysis: Methodological Foundations, Springer (Lecture Notes in Computer Science) 2005.
12. Strogatz, S., Sync: How Order Emerges from Chaos in the Univerise, Nature, and Daily Life, Hyperion Books, 2003.
13. Watts, D. Small Worlds: The Dynamics of Networks between Order and Randomness, Princeton University Press, 1999.
14. Caldarelli, G. Scale-Free Networks, Oxford University Press, 2007.

HOMEWORK: Homework emphasizing and extending lecture material will be assigned and graded. Late homeworks are not accepted except in the case of an unanticipatable absence (e.g. serious illness, death in the family, loss of your favorite DVD etc.).

GRADES: There will be a midterm exam and a course project. Each will count 30% of the final course grade. The exam will be "almost closed book," i.e. you may use two 8.5 by 11 inch sheet of notes. Such notes may be on both sides of the paper, but they should be in orginal pen or pencil, **not photo-copies**. Homework assignments and Quizzes will be given periodically throughout the semester and together will count 30% of the final course grade. Some homework assignments will involve programming and the use of optimization software. Finally, class discussion will be critical. 10% of the course grade will reflect your participation and insightfulness in class discussions.