Self-Assessment & Capability Description
LDRD-DR Project 20040141
Statistical Physics of Infrastructure Networks

Eli Ben-Naim, PI

April 16, 2006

1 People

1.1 Leadership

- PI: Eli Ben-Naim (T-13)
- co-PI: Matthew Hastings (T-13), Zoltan Toroczkai (T-13)

1.2 Staff members (23)

- T-7: Aric Hagberg, Pieter Swart
- T-10: Alan Perelson
- T-12: Cynthia Reichhardt
- T-13: Eli Ben-Naim, Matthew Hastings, Charles Reichhardt, Alan Lapedes, David Sharp, Shuling Hou
- T-CNLS: Zoltan Toroczkai
- CCS-3 Marian Anghel, Allon Percus
- CCS-5 Gabriel Istrate, Christian Reidys, Andres Hansson, Steven Eubank, Madhav Marathe, Anil Kumar
- D-1 Nicholas Hengartner
- D-3 Kenneth Werley
- D-5 Brian Bush, Loren Toole

1.3 Postdocs (9)

- T-CNLS/T-13: Adilson Motter, Erszebet Ravacz, Eduardo Lopez, Yeo-Jin Chung, Hasan Guclu
- T-7 Gerardo Chowell, Joel Miller, Natali Gulbahce
- CCS-5 Anil Kumar Vulikanti

1.4 Students (21)

- T-CNLS/T-13: Balacz Kozma (RPI), Eduardo Lopez (Boston), Federico Vazquez (Botson), Pu Chen (Boston), Sun Jin Park (Korea), Sameet Shreenivasan (Boston), Jin Sub Kim (Seoul), Vishal Sood (Boston), Andras Libal (Notre Dame), Thomas Womack (Cornell),
- T-7 Hernan Rozenfeld (Clarkson), Gerardo Chowell (Cornell), Crystal Linkletter (Simon Fraser), Katie Bold (Princeton), Joel Miller (Cambridge), Jim Bagrow, Ignacio Rozada
- CCS-5 Vaishnavi Krishnamurthy (UC Riverside), R Raman (Iowa), Z Svytkina (Cornell)
- CCS-3 Bruno Concalves (Emory)

1.5 Visitors (17)

- Long Term: Sidney Redner (Boston), Byungnam Kahng (Seoul), Kevin Bassler (Houston), George Korniss (RPI), Shlomo Havlin (Bar-Ilan), Paul Krapivsky (Boston), Tibor Antal (Boston), Lidia Braunstein (Boston), Dan Schult (Colgate), Richard Jordan (Mount Holyhoke College), G. Pandurangan (Purdue), M. Vardi (Rice)
- Short Term: Daniel ben-Avraham (Clarkson), Alessandro Vespigniani (Indiana), Juyong Park (Michigan), Slava Ispolatov (Santiago), Takashi Nishikawa (SMU)

1.6 External Collaborators (22)

- Sidney Redner (Boston), Eugene Stanley (Boston), Shlomo Havlin (Bar-Ilan), George Korniss (RPI), Kevin Bassler (Houston), Takashi Nishikawa (SMU), Juergen Kurths (Dresden), Byungnam Kahng (Seoul), Dan Schult (Colgate), Richard Jordan (Mount Holyhoke College), Manos Renieris (Google), David Aldous (Berkeley), Stefan Boettcher (Emory), Michalis Faloutsos (UC Riverside), Emilio Frazzoli (UCLA), M. Marathe (Virginia Tech), V. Anil Kumar (Virginia Tech), S.S. Ravi (SUNY Albany), G. Pandurangan (Purdue), C. Moore (UNM), M. Vardi (Rice), C. Homan (Rochester Institute of Technology).

2 Key Capabilities Developed

- Statistical tools for analysis of human contact networks.
- Vaccination strategy for urban epidemic outbreaks.
- Power-grid vulnerability analysis simulation tools.
- Development of influenza surveillance methodologies.
- Scaling theory for threshold epidemics.
- Mean-field theory for small-world networks
- Series expansion for calculating percolation properties on networks.
- Comprehensive scaling and renormalization theory for small-world networks.
- Comprehensive kinetic theory formulation for random networks.
- Perturbation theory in disorder for small-world networks.
- Network representation of protein conformations.
- Methodology for identifying communication bottlenecks in communication networks.
- Efficient algorithms for routing in packet-switched networks under intense driving.
- New characterization of transport properties of random networks.
- Network visualization and analysis using Python.
- Exact methods for anlyzing diffucion and synchronization on networks
- Spectral analysis of networks.
- Multiscale analysis methods for networks.
- Topology-preserving reduction procedure for massive graphs.
- Algorithmic characterization of phase transition in network problems.

- Model of network traffic that incorporates packet reordering.
- measures for capacity of the MAC layer of communication networks.

3 Conferences and Meetings Organized (12)

- Socio-technical Systems: Bridging the Scales, August 14-18, 2006. Los Alamos, New Mexico.
- Challenges and Opportunities in Distributed Sensor Networks March 9-10, 2006, Los Alamos, New Mexico.
- Optimization in Complex Networks, June 19-22, 2006, Los Alamos, New Mexico.
- Dynamics on Complex Networks and Applications, February 06 - March 03, 2006. Max Plank Institute for Physics of Complex Systems, Dresden Germany.
- Meeting of the National Academy of sciences on agent based modeling, October 2005, Los Alamos, New Mexico.
- DARPA-LANL meeting on networks science, December 6, 2005, Los Alamos, New Mexico.
- Collectives Formation and Specialization in Biological and Social Systems April 20-22, 2005, Santa Fe, New Mexico, 2005.
- Organized session on simulation of infrastructure networks at the LACSI 2conference, 2005.
- Summer school on networks and high-dimensional data mining, IPAM ,UCLA, 2005.
- Symposium "Phase Transitions and Computer Science" at AAAS Annual Meeting, Seattle, 2004.
- Statistical Physics of Complex Systems, Los Alamos, New Mexico, July 26-August 6, 2004.
- Complex Networks: Structure, Function, and Dynamics, Santa Fe, New Mexico, May 12-16, 2003.

4 Media Highlights

- Atlantic Monthly, 04/06.
- Discover Magazine, 03/06.
- New York Times 03/06.
- Nature 01/06.
- New Scientist 01/06.
- MSNBC TV 01/06.
- Forbes 01/06.
- Reuters 01/06.
- BBC News 01/06.
- New Scientist 03/05.
- New York Times 01/04.
- MSNBC 05/04.
- ABQ Tribune 05/04.
- ABC News 05/04.
- Forbes 05/04.
- Reuters 05/04.

5 Books (2)

1. Complex Networks,
   E. Ben-Naim, H. Frauenfelder, Z. Toroczkai, Editors.
   Lecture Notes in Physics 650 (Springer, Berlin, 2004).

2. Computational Complexity and Statistical Physics,
   A. G. Percus, G. Istrate and C. Moore, Editors.
   Oxford University Press, New York, 2005.

6 Publications (57)

Not listed below are 20-30 submitted and in press publications.

1. Scaling in small-world resistor networks
   G. Korniss, M. B. Hastings, K. E. Bassler, M. J. Berryman, B. Kozma, D. Abbott
   Phys. Lett. A **350**, 324 (2006).

2. On the structure of Competitive Societies,
   E. Ben-Naim, F Vazques, and S. Redner,
   Eur. Phys. Jour. B **49**, 531 (2006).

3. Universal behavior of optimal paths in weighted networks with general disorder,
   Y. P. Chen, E. Lopez, S. Havlin, H. E. Stanley,
   Phys. Rev. Lett. **96**, 068702 (2006).

4. G. Istrate, A. Hansson, S. Thulasidasan M.V. Marathe, C. Barrett, Semantic Compression of TCP Traces, in Proceedings of the 5th IFIP Networking Conference (NETWORKING'06).

5. Diffusion processes on power-law small-world networks
   B. Kozma, M. B. Hastings, G. Korniss,
   Phys. Rev. Lett. **95**, 018701 (2006).

6. Scalability, Random Surfaces and Synchronized Computing =20 Networks,
   Z. Toroczkai, G. Korniss, M. A.Novotny, and H. Guclu,
   in "Computational Complexity and Statistical Physics" Eds. A. Percus, G. Istrate and C. Moore, Oxford Univ. Press, pp. 249, (2006).

7. Universality in the synchronization of weighted random networks,
   C. S. Zhou, A. E. Motter, J. Kurths,
   Phys. Rev. Lett. **96**, 034101 (2006).

8. Provable Algorithms for Parallel Sweep Scheduling on Unstructured Meshes
   V.S. Anil Kumar, M. Marathe, S. Parthasarathy, A. Srinivasan and S. Zust

International Parallel and Distributed Processing Symposium (IPDPS), 2005.

9. Dynamics of social balance on networks,
T. Antal, P. L. Krapivsky, S. Redner,
Phys. Rev. E **72**, 036121 (2005).

10. Parametric probabilistic routing in sensor networks,
C. Barrett, S. J. Eidenbenz, L. Kroc, M. Marathe, J. P. Smith,
Mob. Net. and Appl. **10**, 529 (2005).

11. What is the most competitive sport?
E. Ben-Naim, F Vazques, and S. Redner,
physics/0512143 (2005).

12. Chronological Rank in Biological Evolution,
E. Ben-Naim and P. L. Krapivsky,
J. Stat. Mech. L10002 (2005).

13. Polymerization with Freezing,
E. Ben-Naim and P. L. Krapivsky,
J. Phys. Cond. Matter **17**, S4249 (2005).

14. Dynamics of Social Diversity
E. Ben-Naim and S. Redner,
J. Stat. Mech. L11002 (2005).

15. Percolation with Multiple Giant Clusters
E. Ben-Naim and P. L. Krapivsky,
J. Phys. A, **38**, L417 (2005).

16. Kinetic Theory of Random Graphs,
E. Ben-Naim and P. L. Krapivsky,
AIP Conference Proceedings **776**, 3 (2005).

17. Opinion Dynamics: Rise and Fall of Political Parties
E. Ben-Naim,
Europhys. Lett. **69**, 671 (2005).

18. Kinetic Theory of Random Graphs: from Paths to Cycles,
E. Ben-Naim and P. L. Krapivsky,
Phys. Rev. E **71**, 026129 (2005).

19. Consensus formation in multi-state majority and plurality models,
P. Chen, S. Redner,
J. Phys. A **38**, 7239 (2005).

20. Statistical mechanics of interfering links,
M. B. Hastings,
Phys. Rev. E **72**, 015102 (2005).

21. Processes on annealed and quenched power-law small-world networks,
B. Kozma, M. B. Hastings, G. Korniss,
Proceedings of SPIE **5845**, 130 (2005).

22. Network growth by copying,
P. L. Krapivsky, S. Redner,
Phys. Rev. E **71**, 036118 (2005).

23. Reducing large Internet topologies for faster simulations,
V. Krishnamurthy, M. Faloutsos, M. Chrobak, L. Lao, J. H. Cui, A. G. Percus,
Lecture Notes in Computer Science **3462**, 328 (2005).

24. Threshold properties of random boolean constraint satisfaction problems,
G. Istrate,
Disc. Appl. Math. **153**, 141 (2005).

25. Spines of random constraint satisfaction problems: definition and connection with computational complexity,
G. Istrate, S. Boettcher, A. G. Percus,
Ann. Math. and Art. Intell. **44**, 353 (2005).

26. End-to-End Packet-Scheduling in Wireless Ad-hoc Networks,
V.S. Anil Kumar, M. Marathe, S. Parthasarathy and A. Srinivasan
Proceedings of the ACM Symposium on Discrete Algorithms (SODA 2004).

27. A continuous-discontinuous second-order transition in the satisfiability of random Horn-SAT formulas,
C. Moore, G. Istrate, D. Demopoulos, M. Y. Vardi,
Lect. Notes in Comp. Sci. **3624**, 414 (2005).

28. Citation statistics from 110 years of Physical Review,
S. Redner,
Physics Today **58**, 49 (2005).

29. On certain morphisms of sequential dynamical systems,
C. M. Reidys,
Disc. Math. **245**, 296 (2005).

30. Voter model on heterogeneous graphs,
V. Sood, S. Redner,
Phys. Rev. Lett. **94**, 178701 (2005).

31. Agent-based modeling as a decision-making tool,
Z. Toroczkai, S. Eubank, The Bridge (Natl. Acad. of Eng.) **35**, 22 (2005).

32. Optimization of influenza vaccine selection,
J. T. Wu, L. M. Wein, A. S. Perelson,
Oper. Res. **53**, 456 (2005).

33. The distance-2 matching problem and its relationship to the MAC-layer capacity of ad hoc networks,
H. Balakrishnan, C. Barrett, V. S. Anil Kumar, M. Marathe, S. Thite,
IEEE Jour. Sel. Areas in Comm. **22**, 1069 (2004).

34. Unicyclic Components in Random Graphs,
E. Ben-Naim and P. L. Krapivsky,
J. Phys. A **37**, L189 (2004).

35. Size of Outbreaks Near the Epidemic Threshold,
E. Ben-Naim and P. L. Krapivsky,
Phys. Rev. E **69**, 050901R (2004).

36. Finite size Fluctuations in Interacting Particle Systems,
E. Ben-Naim and P. L. Krapivsky,
Phys. Rev. E **69**, 046113 (2004).

37. Extremal Properties of Random Structures,
E. Ben-Naim, P. L. Krapivsky, and S. Redner,
Lecture Notes in Physics **650**, 211 (2004).

38. Leadership Statistics in Random Structures,
E. Ben-Naim and P. L. Krapivsky,
Europhys. Lett. **65**, 151-157 (2004).

39. Extremal optimization at the phase transition of the three-coloring problem,
S. Boettcher, A. G. Percus,
Phys. Rev. E **69**, 066703 (2004).

40. Recognition of homo- and heterosubtypic variants of influenza A viruses by human CD8+ T lymphocytes,
A. C. M. Boon, G. de Mutsert, D. van Baarle, D. J. Smith, A. S. Lapedes, R. A. M. Fouchier, K. Sintnicolaas, A. D. M. A. Osterhaus, G. F. Rimmelzwaan,
Jour. Immun. **172**, 2453 (2004).

41. Predicting the impact of a nonsterilizing vaccine against human immunodeficiency virus,
M. P. Davenport, D. I. Chao, R. M. Ribeiro, A. S. Perelson,
J. Virol. **78**, 11340 (2004).

42. Modelling disease outbreaks in realistic urban social networks,
S. Eubank, H. Guclu, V. S. Kumar, M. V. Marathe, A. Srinivasan, Z. Toroczkai, N. Wang,
Nature **429**, 180 (2004).

43. Locality in quantum and Markov dynamics on lattices and networks,
M. B. Hastings,
Phys. Rev. Lett. **93**, 140402 (2004).

44. Roughness Scaling for Edwards-Wilkinson Relaxation in Small-World Networks,
B. Kozma, M. B. Hastings, G. Korniss,
Phys. Rev. Lett. **92**, 108701 (2004).

45. An ϵ-expansion for small-world networks,
M. B. Hastings,
Eur. Phys. Jour. B **42**, 297 (2004).

46. Neutral evolution and mutation rates of sequential dynamical systems,
H. S. Mortveit, C. M. Reidys,
Adve. Comp. Sys. **7**, 395 (2004).

47. Reduction of discrete dynamical systems over graphs,
H. S. Mortveit, C. M. Reidys,
Adv. Comp. Sys **7**, 1 (2004).

48. Mapping the antigenic and genetic evolution of influenza virus,
D. J. Smith, A. S. Lapedes, J. C. de Jong, T. M. Bestebroer, G. F. Rimmelzwaan, A. S. M. Osterhaus, R. A. M. Fouchier,
Science **305**, 5682 (2004).

49. Jamming is limited in scale-free systems,
Z. Toroczkai, K. E. Bassler,
Nature **428**, 6984 (2004).

50. Scaling and universality in continuous length combinatorial optimization,
D. Aldous, A. G. Percus,
Proc. Nat. Acad. of Sci. USA **100**, 1121 (2003).

51. ETS IV: Sequential dynamical systems: fixed points, invertibility and equivalence
C. L. Barrett, H. S. Mortveit, C. M. Reidys,
App. Math. Comp. **134**, 153 (2003).

52. Bifurcations and Patterns in Compromise Processes,
E. Ben-Naim, P. L. Krapivsky, and S. Redner,
Physica D **183**, 190-204 (2003).

53. Mean-field and anomalous behavior on a small-world network.
M. B. Hastings,
Phys. Rev. Lett. **91**, 098701 (2003).

54. Random vibrational networks and the renormalization group,
M. B. Hastings,
Phys. Rev. Lett. **90**, 148702 (2003).

55. Competition-driven network dynamics: emergence of a scale-free leadership structure and collective efficiency,

M. Anghel, Z. Toroczkai, K. E. Bassler, G. Korniss,
Phys. Rev. Lett. **92**, 058701 (2004).

56. Suppressing roughness of virtual times in parallel discrete-event simulations,
G. Korniss, M. A. Novotny, H. Guclu, Z. Toroczkai, P. A. Rikvold,
Science **299**, 677 (2003).

57. Scaling laws for the movement of people between locations in a large city,
G. Chowell, J. M. Hyman, S. Eubank, C. Castillo-Chavez,
Phys. Rev. E **68**, 066102 (2003).