Chris Budd and Johannes Zimmer Second Semester 2009–2010

MA50200 Topic Review in Applied Mathematics

1 *Inverse Problems*

Here are some possible topic areas:

- The Kalman Filter and its applications
- Electrical Impedence Tomography
- The Radon transform
- Medical applications of tomography
- Data assimilation (incorporating data into a forecast model, particularly relevant to meteorology)
- Regularisation of inverse problems
- Imaging the ionosphere (a review of the work of the INVERT Centre in Bath)

Here are some useful references (in addition, the Wikipedia articles on Kalman filtering and Data Assimilation are both instructive):

[1] Eric Todd Quinto. An introduction to X-ray tomography and Radon transforms. In *The Radon transform, inverse problems, and tomography*, volume 63 of *Proc. Sympos. Appl. Math.*, pages 1–23. Amer. Math. Soc., Providence, RI, 2006.

[2] F. Natterer. *The mathematics of computerized tomography*, volume 32 of *Classics in Applied Mathematics*. Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 2001. Reprint of the 1986 original.

[3] Margaret Cheney, David Isaacson, and Jonathan C. Newell. Electrical impedance tomography. *SIAM Rev.*, 41(1):85–101 (electronic), 1999.

[4] Robert Kohn and Michael Vogelius. Determining conductivity by boundary measurements. *Comm. Pure Appl. Math.*, 37(3):289–298, 1984.

[5] Luis Tenorio. Statistical regularization of inverse problems. *SIAM Rev.*, 43(2):347–366 (electronic), 2001.

[6] Arnold Neumaier. Solving ill-conditioned and singular linear systems: a tutorial on regularization. *SIAM Rev.*, 40(3):636–666 (electronic), 1998.

[7] D. Rozier, F. Birol, E. Cosme, P. Brasseur, J. M. Brankart, and J. Verron. A reduced-order Kalman filter for data assimilation in physical oceanography. *SIAM Rev.*, 49(3):449–465 (electronic), 2007.

[8] G. S. Bust and C. N. Mitchell. History, current state, and future directions of ionospheric imaging. *Reviews of Geophysics*, 46(1), 2008.

2 *Networks*

Here are some possible topic areas:

- Social networks, scientific collaborations
- Six degrees of separation
- Small world networks
- The internet, viruses and network models for them
- Google
- Network models of epidemics
- Percolation models
- Emergent properties in networks: scaling laws and clustering
- Mazes, their history and how to solve them

Some useful references are:

[1] Albert-László Barabási, Zoltán Dezső, Erzsébet Ravasz, Soon-Hyung Yook, and Zoltán Oltvai. Scale-free and hierarchical structures in complex networks. In *Modeling of complex systems*, volume 661 of *AIP Conf. Proc.*, pages 1–16. Amer. Inst. Phys., Melville, NY, 2003.

[2] Kurt Bryan and Tanya Leise. The $25,000,000,000 eigenvector: the linear algebra behind Google. *SIAM Rev.*, 48(3):569–581 (electronic), 2006.

[3] D.J. Watts and S.H. Strogatz. Collective dynamics of 'small-world' networks. *Nature*, 393(6684):440–442, 1998.

[4] Duncan S. Callaway, M. E. J. Newman, Steven H. Strogatz, and Duncan J. Watts. Network robustness and fragility: Percolation on random graphs. *Phys. Rev. Lett.*, 85(25):5468–5471, Dec 2000.

[5] Desmond J. Higham. A matrix perturbation view of the small world phenomenon. *SIAM Rev.*, 49(1):91–108 (electronic), 2007.

[6] Chris H. Q. Ding, Hongyuan Zha, Xiaofeng He, Parry Husbands, and Horst D. Simon. Link analysis: hubs and authorities on the World Wide Web. *SIAM Rev.*, 46(2):256–268 (electronic), 2004.

[7] Noga Alon, Seannie Dar, Michal Parnas, and Dana Ron. Testing of clustering. *SIAM J. Discrete Math.*, 16(3):393–417 (electronic), 2003.

In addition, the Wikipedia article on Six degrees of separation makes an interesting read, (`http://en.wikipedia.org/wiki/Six_degrees_of_separation`).

3 Mathematical Methods for Molecular Simulation

Some possible topic areas are:

- Numerical methods to approximate trajectories
- Shadowing
- Symplectic algorithms
- Transition state theory
- Implementation and paralellisation of algorithms
- Methods for thermostatting
- Monte-Carlo methods

Some references:

[1] Daan Frenkel and Berend Smit. *Understanding Molecular Simulation*, volume 1 of *Computational Science Series*. Academic Press, Inc., Orlando, FL, USA, second edition, 2002.

[2] Benedict Leimkuhler and Sebastian Reich. *Simulating Hamiltonian dynamics*, volume 14 of *Cambridge Monographs on Applied and Computational Mathematics*. Cambridge University Press, Cambridge, 2004.

[3] Frédéric Legoll, Mitchell Luskin, and Richard Moeckel. Non-ergodicity of Nosé-Hoover dynamics. *Nonlinearity*, 22(7):1673–1694, 2009.

[4] Richard E. Gillilan and Kent R. Wilson. Shadowing, rare events, and rubber bands. a variational Verlet algorithm for molecular dynamics. *J. Chem. Phys.*, 97(3):1757–1772, 1992.

[5] Weinan E and Eric Vanden-Eijnden. Towards a theory of transition paths. *J. Stat. Phys.*, 123(3):503–523, 2006.

[6] Holger Waalkens, Roman Schubert, and Stephen Wiggins. Wigner's dynamical transition state theory in phase space: classical and quantum. *Nonlinearity*, 21(1):R1–R118, 2008.

4 Inverse Problems

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