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Final Report on Characterizing the Dynamics of Spatio-Temporal Data

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Summary

One principal goal of the grant was to model and analyze the dynamics of spatially extended chaotic systems. One of the principal tools used in the analysis was KLTOOL, a computer package developed by the principal investigators for Karhunen-Loève analysis. The package was used to analyze video data from a laboratory experiment, performed by Michael Gorman and collaborators at the University of Houston, on cellular flames. A wide variety of complex dynamics are observed depending on factors such as the mix of reactants and ambient pressure. At present, there is no satisfactory mathematical model of the dynamics, but the Ph.D. research of José Palacios, who was supported by this grant, showed that in many cases the dynamics were relatively low dimensional, and he was able to characterize the behavior of the flames in terms of periodic saddle orbits. The K-L analysis was also used to analyze the apparent symmetries that govern the dynamical behavior of a certain two-dimensional model of fluid flow; this work was completed by Nejib Smaoui, a graduate student and postdoc in the mathematics department in collaboration with D. Armbruster and others.

A second goal of the project was to analyze complex time series whose underlying dynamics may be low dimensionally chaotic. Particular emphasis was placed on systems of possible relevance to energy production and distribution. The work with Stuart Daw and collaborators attempted to characterize low-dimensional aspects of the dynamics of a fluidized bed, in

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particular, a transition from periodic to irregular behavior. E. Kostelich worked with Efrain O'Neill, who is a graduate student in electrical engineering, and G. Heydt, a faculty member in the Department of Electrical Engineering at ASU, to characterize the dynamics of an electric arc furnace and to construct a power quality model that incorporates chaotic (as opposed to stochastic) forcing from the arc furnace. The model's output appears to mimic observed "real-world" measures of power quality much better than models that assume entirely stochastic behavior in arc furnaces. This work will appear in the *IEEE Transactions on Power Quality*.

Finally, E. Kostelich and collaborators worked on aspects of targeting in chaotic dynamical systems. This work showed that it is possible to switch a moderately high-dimensional chaotic process rapidly between prespecified periodic saddle orbits embedding within the attractor. Additional work extended previously-developed algorithms for the highly accurate computation of stable manifolds of periodic saddle orbits, which is essential to the successful application of targeting algorithms.

Graduate students supported by the grant

- J. Palacios, Ph.D. in mathematics awarded May 1995.
- M. Mincheva; Master's degree in mathematics awarded May 1997.
- I. Diaz-Rivera; Ph.D. in mathematics awarded May 1998. She is writing up her work for publication in Fall 1998.
- W. Qian, Ph.D. in mathematics awarded May 1997.

Research papers resulting from the grant support

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2. E. J. Kostelich, I. Kan, C. Grebogi, E. Ott, and J. A. Yorke, "Unstable dimension variability: a source of nonhyperbolicity in chaotic systems," *Physica D*, **109** (1997), 81-90.
3. D. Armbruster and N. Smaoui, "Symmetry and Karhunen-Loève Analysis," *SIAM J. of Scientific Computing* **18** (1997), 1526-1533.
4. E. Barreto, F. Casas, C. Grebogi, and E. J. Kostelich, "Control of Chaos: Impact Oscillators and Targeting," in *IUTAM Symposium on*

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