GROWTH AND NONLINEARITY

Final Project Report

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The aims of this proposal were achieved. The program covered by this grant has had three major themes: Fractal growth, pattern formation and the analysis of complexity; that is, the effects of random processes in creating hidden order in statistical system, the interplay between this hidden order and macroscopic order, and the analysis of these complex systems. For example a dendritic crystal such as a snowflake has a complicated and beautiful pattern with much evidence of the underlying six-fold symmetry of ice. It is a pattern forming system. However, in a disordered environment (such as growth on a rough or dirty surface) this order is replaced by a new order, the fractal or scaling symmetry of a disordered crystal. In this case every part of the crystal is similar on the average to the whole (up to a change in scale.) The description of these new kinds of order may require the introduction of new analytic and numerical methods. We made significant progress in all of the areas proposed.

We concentrated on the following specific problems:

- We looked at spiral patterns in certain chemical reactions, and using the generalizing power of our techniques by applying them to a biological pattern-forming system, slime molds.
- We considered the fractal patterns of the noise driven roughness of rapidly growing thin films, a subject of extreme technological significance. We found, to our surprise, that the major process which limits the production of smooth films in a very common case was the formation of a pattern, a large, shallow mound on the surface which our colleagues found experimentally and we explained theoretically. This work has had considerable impact.
- We pioneered the numerical study of island formation in heteroepitaxy, and, together with the experimental group of B. G. Orr, compared to experiment. Our work was one of the first contributions to what is now a very active field, that of quantum dot formation.
- We contributed to the study of the disorderly motion of the flux lattice in superconductors and related it to generalized notions of scaling.
- We reviewed the general field of disorderly diffusion-limited growth with a view to discerning the beginnings of a general theoretical approach. Our work in these areas has had an important impact on the field, and many of our papers are very often cited.

We developed a theory of 'growth oscillations'. These are oscillations which are generically to be expected in the growing interfaces, and result from a beating between two microscopic length scales: the size of the particle aggregating on the interface, and the penetration depth of atypical particle into the surface. This latter length could be dependent on the dynamics of the process. We found that these oscillations are generically quasi-periodic.

We also devoted a great deal of attention to the analysis of nonlinear systems that form complex patterns in space and time. We developed new techniques for the analysis of such systems, and applied them to a number of interesting cases. The methods we developed have been used by many other researchers, and are applicable to a wide range of complex systems including spin glasses and highly turbulent flow. In our own applications, we have used these methods to develop new dynamical insights in several fields, in particular, turbulent flow, economics and finance and epilepsy. In the latter case, we have shown, using these methods, that the occurrence of epileptic seizures are not randomly distributed in time, but contain some degree of predictability.

We have studied the structural and electronic properties of a set of layered materials built up by substitutional algorithms, including the well-known, Thue-Morse system. We also showed that a class of materials built up by substitutional algorithms have multifractal properties.

Educational Impact

This grant has provided complete or partial support for the Ph.D. theses of the following people:

R. Baiod
Z. Cheng
M. Green
G. Li
J. Li
R. Manuca

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