Book Review

Bifurcation and Chaos:
Analysis, Algorithms, Applications

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Ed. by R. Seydel, F. W. Schneider, T. Küpper, H. Troger

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The title of this book was the theme of a conference held in Würzburg, Germany in August 1990, and its contents are the conference proceedings. The title gives the broad thrust of most of the 49 articles, but the variety and breadth of nonlinear phenomena to be found here covers a wide area of science and engineering, including what we normally think of as the nonphysical sciences, chemistry and biology. This diversity makes the book attractive from the perspective of a scientist. The applications of nonlinear dynamics considered here include gas combustion, chemical oscillators, Rayleigh-Bénard convection, elasticity, the rolling of a ship, the stability of a rotating satellite, robot control, climatic modelling, pattern formation, hydrostatics, electronic circuitry and much more! If one ever needs reassurance about the relevance of (applied) mathematics within the world of science and engineering, just browse through this book.

There are several articles which are purely mathematical, and many more which deal with numerical analysis or computational aspects of problems. The attraction for the applied mathematician is the range of different mathematical models employed. The use of nonlinear ordinary and partial differential equations still dominates, and most of the standard examples like the Duffing, reaction-diffusion and nonlinear Laplace equation appear in

various guises. The treatment of many problems combines analytical, numerical and experimental approaches. The language of nonlinear dynamics is assumed throughout, but for most articles, a knowledge at the level of an introductory text, such as Wiggins [1], should suffice.

Without giving undue emphasis to any particular article, for the purpose of illustration of the complexity of some of the models used, I will mention a model, discussed in several articles, namely a nonlinear chemical oscillator called the *Brusselator*, [2], (which has nothing whatsoever to do with EU funding!). This describes a chemical conversion $A+B \to D+E$ via the intermediates X and Y. The latter undergo a trimolecular autocatalysis $2X+Y \to 3X$:

$$\begin{aligned} A &\xrightarrow{k_1} X \\ X + B &\xrightarrow{k_2} Y + D \\ 2X + Y &\xrightarrow{k_3} 3X \\ X &\xrightarrow{k_4} E \end{aligned}$$

There is an influx of species A and B into the reaction

$$\begin{aligned} A^{in} &= A_0^{in} \\ B^{in} &= B_0^{in}(1 + \alpha \cos \omega t) \end{aligned}$$

that is, there is a constant influx of A while the influx of B varies sinusoidally. The system of differential equations describing this reaction is:

$$\begin{aligned} \frac{dA}{dt} &= -k_1 A + k_f(A^{in} - A) \\ \frac{dB}{dt} &= -k_2 BX + k_f(B^{in} - B) \\ \frac{dX}{dt} &= k_1 A - k_2 BX + k_3 X^2 Y - k_4 X - k_f X \\ \frac{dY}{dt} &= k_2 BX - k_3 X^2 Y - k_f Y \end{aligned}$$

where k_f (a control parameter) is the flow rate through the "Continuous Flow Stirred Tank Reactor" described in [3]. The authors of that article then add a 1% Gaussian white noise to each variable and they assign physically realistic values to the parameters. The result of a Runge-Kutta integration of the model demonstrates that the transition between high and low amplitude oscillations is characterized by a secondary periodic Hopf bifurcation, and that the extent of this transition varies with the noise frequency, in qualitative agreement with the sharp pulses of chemiluminescence observed in a luminol oscillator experiment.

The articles in this text, with a few exceptions (primarily those not written with TEX), knit together quite well visually, allowing for the difficulties in imposing uniformity of format for conference proceedings. However, some of the graphics would benefit from the addition of colour to this monochrome text. Another minor criticism relates to the contents, which are given only in alphabetic order, by name of the first author. The editors justify this on the basis that many papers contain overlapping themes, but an extra two or three pages given to a classification by subject or theme would have been a useful addition.

This book undoubtedly deserves a place in a mathematics library, but should also find a place on the shelves of the practitioners of differential equations, numerical analysis and dynamical systems.

References

[1] S. Wiggins, Introduction to Applied Nonlinear Dynamical Systems and Chaos. Springer–Verlag, 1990.

[2] I. Prigogine and R. Lefever, J. Chem. Phys. **48**, (1968) 1695.

[3] J. Amrehn *et al.*, pp.19–25, *op. cit.*

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