Book Review

Applied Chaos by Jong Hyun Kim and John Stringer. Published by Wiley-Interscience, New York, 1992. $ 99.95, 576 pp.

Much progress has been made recently in the development of chaos theory. This has left many engineers and applied scientists wondering, how can chaos theory be used to enhance the mathematical models used to analyze every day applications? *Applied Chaos* (ISBN 0-471-54453-1) edited by Jong Hyun Kim and John Stringer is an attempt to answer this question. The book contains 20 articles of varying topics each with the common thread of an application of chaos theory. The book is over 500 pages.

During December 4–7, 1990, the International Workshop on Applications of Chaos was held in San Francisco. The book, *Applied Chaos*, contains the lectures presented during this workshop. Showing what can be done and what can be said about chaos theory appears to be the key goal of the authors. Chaos is not an exception in nature, but rather normal in even "simple" phenomena. In order to demonstrate this, the editors present a number of articles about an array of topics such as the chaotic behavior of conveyor belts, atmospheric flight dynamics, mixing, heat transfer, flame dynamics, electrocardiograph data, physiology and medicine and catastrophe theory.

Because *Applied Chaos* is a collection of many articles written by different authors, each chapter assumes different levels of understanding from the reader. For instance, some articles target engineers as the audience. Others articles target professionals from the medical community. The majority of the articles do assumes some understanding of chaos and chaotic theory. This is not an introductory text in chaos. The reader should be familiar with concepts such as strange attractors, bifurcations, and why Lyapunov exponents are so important to the study of chaotic behavior.

One point that the book tries to make is that even though a system may exhibit chaos, this behavior may not be undesirable. The articles show numerous examples as to where chaos is actually beneficial. For instance, the amount of heat transferred through convection can many times be increased with little increase in the power required as input by turbulent (chaotic) fluid flow. Chaos is also beneficial if two different fluids are being mixed. Chaotic mixing can be used in many chemistry and chemical engineering applications. Chaos also plays a hand in the control of heart rate variability.

Chaotic behavior can create undesirable situations. Traditionally, engineers and applied scientists endeavor to build their systems in the realm of linear behavior. An unforeseen force can sometimes induce chaotic behavior in the system. This can lead to disaster. Such is the case of the Tacoma Narrows Bridge catastrophe. Chaos theory is now being used to model these situations, and perhaps these situations can be avoided. Currently, most application of chaos theory in this respect is a priori or after the fact. Chaotic behavior is modeled after it is observed in the physical world.

The bulk of the book is made up of articles of many different topics with a commonality of an application of chaos theory. The articles are loosely broken up into five sections. The first section is chaos theory applied to engineering and technical applications. This section covers subjects such as the dynamics of aircraft, turbulent fluid flow and mixing, and chaotic convective heating. The second section is the application of chaos to the physical sciences. Application of chaos theory to the physiological sciences is the third section. This is followed by a section about chaotic time series and forecasting. Finally, a general topics section is presented. It is in this section that the power of chaos, the sudden change of a chaotic attractor phenomena and the future of chaos theory is contemplated.

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The first section of *Applied Chaos* tries to bridge the gap between chaos theory and applications of an engineering or technological nature. Chaos theory is applied in a number of ways to applications of ship stability, machine dynamics, powered flight, heat transfer and chemical engineering. This not only shows how the new science of chaos can be applied, but also quells skepticism of chaos theory applied to real engineering systems.

Many of the articles apply chaos theory to fluid dynamics. Chaotic behavior can be observed when the fluid enters into turbulent flow. For instance, the dynamics of aircraft is actually the study of two interacting systems: the fluid system and the vehicle itself. Aircraft behavior can become quite unpredictable due to the chaotic nature of the fluid and its interaction with the vehicle. In this application, chaos can lead to disaster and loss of life and should be avoided. Chaos can be quite useful though in other fluid applications such as convective heat transfer or the mixing of two different fluids. In fact, considerable improvements have been made in the understanding of stirring and mixing. This is due in large part to the introduction of chaotic dynamics theory. Chaos theory has also shed light on phenomena once thought to be too complex for a proper analysis.

The second section of *Applied Chaos* presents applications of chaotic theory to the physical sciences. The articles in this section touch upon topics of the chaotic behavior of coupled diodes, flame dynamics and metal-passivation models. The third section applies chaos concepts to the physiological sciences. This section includes articles applying chaos theory to electrocardiograph data and other physiologic problems. Chaos theory can be used to model the dynamics of the heart rate prior to cardiac arrest. This may help doctors diagnose a heart attack before it occurs. Other applications in cardiology include modeling the heart rate with drug toxicity as well as modeling the heart rate with age.

The subject of the fourth section of *Applied Chaos* is modeling time series data with chaos theory. This section includes an article of the theory and application of nonlinear modeling of chaotic system over time. This is an important topic because many systems exhibit chaotic behavior in time as well as the spatial dimensions. The section concludes with some comments about exploiting chaotic dynamics in forecasting catastrophe.

The final section of the text discusses topics such as the power of chaos, the dynamics of chaotic attractors in general, and the future use of chaos. Chaos theory is a discipline of growing importance. The understanding and the use of chaos will increase as more scientists try to push their understanding of a problem further into the unknown. Chaos will become a new analysis tool for engineers, applied scientists, professionals of the medical community, biologists and many others. Chaos theory will also continue to be a new fundamental science unto itself.

Many applications can be enhanced by the use of chaos theory. These applications include such diverse subjects such as fluid mechanics which includes the theory of flight, fluid mixtures and chemical reactions, biological systems, medical applications and many more. Currently, most analysis that use chaos theory are "after the fact" or a posteriori. This means that chaos theory is applied to a system after chaotic behavior has been observed. Future direction chaos theory will be to make this topic a viable tool in the prediction of how a system will behave before the system is physically observed.

Applied Chaos is an excellent text containing many different subjects which will appeal to a diverse assortment of people. The major drawback of the book is that it lacks the continuity of a work written by a single author. This drawback is made up by the fact that each article is very different and self contained. This allows the reader to choose which topics are appealing. It also gives some insight to the breadth of the topic of chaos.

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