Preface

Qu'est-ce que le passé, sinon du présent qui est en retard?
Pierre Dac (l'os à moelle, March 1940)

Modeling automatic engines or physiological systems often involves the idea of control because feedback is used in order to maintain a stable state. But much of this feedback require a finite time to sense information and react to it. A popular way to describe this process is to formulate a delay differential equation (DDE) where the evolution of a dependent variable at time t depends on its value at time $t - \tau$. Unfortunately, solving a DDE is a mathematically difficult task. Over the past decade, rapid advances in computational power have revived interest in DDEs. Previously known equations are investigated allowing a better physical understanding of old problems. In addition, new areas of research have appeared. This is, for example, the case of lasers subject to optical feedback, the delayed control of container cranes, or the real-time synthesis of musical instruments.

Oscillatory instabilities are frequently associated with systems described by DDEs. The motivation to study these oscillations then depends on the background of the researcher. For some, these oscillatory instabilities are viewed as a limitation to the performance of a particular device that must be avoided or possibly controlled. In contrast, other researchers have put the unstable behavior to good use making practical devices such as high-frequency optical oscillators.

New mathematical tools and reliable computer software techniques have been developed for DDEs. Here, preference is given to analytical approaches known collectively as asymptotic methods [22, 124], the most useful techniques for finding approximate solutions to equations. It is a revised and largely expanded version of a series of lectures first given at the Université Libre de Bruxelles in 2002–2003, at the Université Joseph Fourier (Grenoble) in 2003, and, more recently, at the University of Utah in 2007. The minimum prerequisites for this book are a facility with calculus, experience with differential equations, and an elementary knowledge of bifurcation theory. The unusual format of this textbook, avoiding rigorous mathematical proofs and concentrating on applications, aims to introduce beginning students as well as experienced researchers to the large variety of phenomena described by DDEs. It has no ambition to review the rich field of DDEs and references have been selected for their historical impact or for the experiments they are describing.

One novelty in this volume is the place given to the figures. They help in understanding the scientific background of a specific application and how a mathematical model is derived. In addition, computer plots compare exact and approximative solutions illustrating the efficiency of the analytical method. The mathematical computations are described in as friendly a manner as possible.

DDE models are used by biologists, physicists, and engineers with different objectives and expectations. This text is meant to serve as an introduction to the rich variety of applications and could be used in a modeling course on DDEs. Some selected parts of this book could provide material for a class on singular perturbation techniques or to stimulate a differential equation class. It is my experience that the combination of illustrations using a projector and compact computations on the blackboard works well to attract the attention of the audience.

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