Book review of Methods in Neuronal Modeling

2nd edition, edited by Christof Koch and Idan Segev
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Van Ooyen, A. (2000). *International Journal of Neural Systems* 10: 331-332.

In order to simulate the behavior of a single neuron, its continuous structure may be sliced into a large number of small segments, or compartments. This is called the "compartmental" approach, and it is this type of modeling approach that *Methods in Neuronal Modeling* largely concentrates upon. In the compartmental approach, continuous partial differential equations are replaced by sets of ordinary differential equations. Advantages of this modeling approach are that it (1) places no restrictions on the properties of each compartment, (2) allows the representation of complex dendritic and axonal branching structures, and (3) permits great flexibility in the level of resolution. As a result, the compartmental approach makes it possible to create realistic models that have a close relationship with the relevant experimental data. Close connection between models and data finds expression in all chapters of this excellent book.

The book focuses on models that are concerned with electrical and chemical signal processing in nervous systems, from the level of individual ionic channels to large-scale neuronal networks. In comparison with the first edition, seven new chapters have been included, while five of the original chapters have been omitted. Chapters have been added on synaptic transmission, dendritic excitability, calcium dynamics, fabrication of analog VLSI neurons, spike train analysis, modeling small neuronal networks, and an analytical approach to modeling local cortical circuits. A new feature is also that tutorials and simulation programs are provided on the Internet.

The discussion, in Chapter 2, of the cable theory for dendritic neurons is used as a starting point to introduce the compartmental approach, which then features in many of the succeeding chapters -- from single-neuron models to network models of detailed neurons. The last chapter is a technical one that deals with numerical methods for solving differential equations; it also shows the relationships between the compartmental approach and other approaches. Compared to the first edition, the compartmental approach has been extended (in Chapters 3 and 12) to cover sophisticated simulation tools such as NEURON and GENESIS.

A potential pitfall of the compartmental approach is that so much detail is put into the model that it becomes almost as complex as reality itself. The model may then be successful in mimicking the behavior we are interested in but will no longer give an understanding of underlying mechanisms or of what is really essential for the behavior being modeled. Stepwise simplifying models while retaining the principle elements of the behavior is a crucial step towards understanding. In a number of chapters, the authors are clearly aware of this. In Chapter 3, compartmental models of complex neurons are compared with reduced models, such as equivalent cylinder approximations. This chapter has also a good general discussion on the issue of the level of detail at which neurons and networks should be modeled in order to produce insightful results. Chapter 5, in which the compartmental approach is applied to modeling active dendritic processes in pyramidal neurons, also discusses the problem of how to deal with a very large number of parameters. In Chapter 10, on modeling small neuronal networks that generate rhythmic firing, model reduction is also an issue along with the problem of "structural instability" in conductance-based models (whether single or multiple compartment). Structural instability means that the behavior of any given model can change dramatically when small modifications are made in its parameter values. A possible solution to this problem, studied in Chapter 10, is to construct models in which the parameters regulating conductances are not fixed but, rather, are dynamic elements of the model itself.

In addition to chapters in which the compartmental approach is used, there is a chapter on the application of analytical methods to simplified network models (for feature selectivity in local cortical circuits, Chapter 13), a chapter on phase-plane analysis of neural excitability and oscillations in simple networks (Chapter 7), and a chapter on the principles of spike train analysis (Chapter 9).

In order to gain true understanding of the brain, experimental work needs to be complemented by theoretical analysis and simulation studies. This book reflects the growing realization that new interdisciplinary research methodologies must be developed that combine experimental and modeling approaches. The book is therefore useful not only for those working in computational neuroscience but also for experimental neuroscientists who want to work in an interdisciplinary manner, as well as for those working in the field of artificial neural networks and wanting to go beyond the "unnatural" simplicity of "point" neurons.

In all chapters, the mathematics of the models and modeling approaches are clearly explained and in most cases require only basic mathematical knowledge. What could have improved the book was a good introductory chapter that set the tone for what is to come and that gave the rationale for including each specific chapter. For the rest, the book is well organized and gives an excellent up-to-date overview of the field of computational neuroscience.