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BOOK REVIEW

Matthew F. Dixon, Igor Halperin, and Paul Bilokon: Machine learning in finance from theory to practice

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In the last decades, the extraordinary technological advancements, and the accelerated speed of information generation and distribution, have made increasingly large datasets of financial data, such as stock returns, widely available and computationally manageable. Thereupon, recent technological developments have led to vast improvements in computational power and increased relevance of machine and statistical learning algorithms. Machine learning has indeed become one of the most influential phrases in the business world and within the financial literature.

There are manifold excellent textbooks on the distinct topic of machine learning, but few present the topic concretely with regard to finance. This book closes the existing gap between quantitative finance and statistical machine learning, as the latter is treated as a nonparametric and nonlinear extension of the first. The book extensively covers two of the three main categories of machine learning algorithms—supervised and reinforcement learning, while unsupervised learning remains out of scope because it does not exhibit many overlaps with financial modeling and computational finance. Overall, the book's focus certainly lies on (inverse) reinforcement learning, which is presented innovatively as a model-free framework for stochastic control problems in finance.

The book is divided into three main parts. The first part *Machine Learning with Cross-Sectional Data* presents supervised machine learning approaches from Bayesian and frequentist perspective with focus on deep learning. The second part *Sequential Learning* covers supervised machine learning for times series data with focus on recurrent and convolutional neural networks. The third part *Sequential Data with Decision-Making* deals with (inverse) reinforcement learning and its applications and is clearly the most emphasized topic, taking up almost 50% of the book's content.

Each part is introduced with background information, examples of relevant practical applications, and references to the most recent scientific literature. Most importantly, before diving into innovative approaches from the field of machine learning, the authors emphasize the technical foundations necessary for fully comprehending a topic, such as

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basic mathematical and statistical concepts, as well as common theories from financial modeling. In this way, the authors demonstrate the relations and intuitions underlying the most elaborate algorithms and manage to lift the common *black-box* perception of machine learning. The book covers all essential areas of machine learning with relevance to quantitative finance. The respective state-of-the-art techniques and algorithms are illustrated both from a theoretical and practical perspective, making the book suitable for academia and practice.

An additional strong advantage of this book is the clear and consistent structure of its chapters. Each chapter follows the same outline, allowing the readers to orientate quickly and promptly find the sections of interest. The concisely defined chapter objectives in the introduction and key learning points in the summary of each chapter help keep track of the content. Moreover, each chapter is accompanied by a reference list that aids more interested readers to continue the research on the specific topic. Although clearly outlined as a feature of the book and an appropriate way for the readers to test their overall understanding, the provided multiple-choice questions cover somewhat randomly the different concepts throughout the book; for example, chapters 5 to 7 do not include any questions. More effective and helpful for the reader are the revision sections where the authors manage to methodically unify theory and practice for each chapter. The more theoretically inclined readers can use the numerous exercises to revise their knowledge on the underlying mathematical and statistical tools, while the practitioners can focus on the examples provided with well-designed and documented Python notebooks. Particularly, the latter allow reproducibility and encourage learning-by-doing, which is a valuable element of a textbook on applications for the practice. Nevertheless, since the Python code acts more as supplementary material and less as an integral part of the chapters, certain links between theory and application are submerged.[1]

Overall, the book covers multiple machine learning approaches with advanced technical exposition and is therefore especially suitable as an academic reference point, especially on Reinforcement Learning. In the final chapter, the authors go one step further and introduce a unified theory of financial decision making that combines supervised and reinforcement machine learning. Unfortunately, no examples are provided, and the theory remains merely conceptual. Regarding the applications in finance, the book is a valuable resource for quantitative investors (quants) and financial modelers to gain information on emerging techniques from the so-called neural network zoo (Leijnen and Veen 2020). Practitioners should bear in mind that some chapters require a solid mathematical background to follow the presented derivations fully. Readers interested in other fields of finance, such as stocks and factor analysis, as well as asset management should refer to the recent works of López de Prado (2018, 2020), who focus on data processing, distance metrics, clustering techniques, and backtest overfitting, or Coqueret and Guida (2020) who focus on cross-sectional factor models.

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[1] In their recently published work, Coqueret and Guida (2020) unintermittedly integrate self-contained R code samples and snippets within the chapters which facilitates the more straightforward application of the transferred theory.

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