Machine Learning in VLSI Computer-Aided Design

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Editors

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To Shaza, Adam, Ella, and Lily

Abe

To Peggy, Will, and Tom

Duane

To Karen and Thomas

Xin

Tell me and I forget.
Teach me and I remember.
Involve me and I learn.

Ben Franklin

Foreword

As an active branch of applied computer science, the field of VLSI computer-aided design (VLSI CAD) has always been at the technological forefront in incorporating cutting-edge algorithms in the software tools and methodologies that electronics engineers have used to weave the digital fabric of our world.

This book amply demonstrates that in line with its historical track record, VLSI CAD has also been at the leading edge in making good use of machine-learning technologies to further automate the design, verification, and implementation of the most advanced chips.

Machine learning and VLSI CAD have in common several main characteristics that may have greatly facilitated their interlock. The first is that they are both consumers of Big Data. In fact, Moore's law has essentially guaranteed that chip data grow exponentially big to the point that having tens of billions of transistors in a chip is now so common and almost taken for granted. The second characteristic that they have in common is a structured approach for controlling complexity. In machine learning, this approach is most apparent in the use of layered networks as inference and generalization engines. In VLSI CAD, complexity is controlled through a well-defined abstraction hierarchy, going from the transistor and its technology as raw data to the chip architecture as a model of processing and computation. The third common characteristic of the two fields is their focus on computational efficiency, be it to shorten turn-around time in chip design, as is the case in VLSI CAD, or to promptly detect patterns in time series as is the case in mission-critical cloud analytics. The fourth common characteristic is a focus on automated optimization and synthesis that VLSI CAD has spearheaded, and synthesis is now becoming an important trend for the design of neural networks in machine learning as well.

It is therefore almost natural to think of VLSI CAD engineers as the original data scientists who have been instrumental not only in dealing with big data in the context of chip design but also in enabling the very chips that have ushered the Big Data era and made it a social and business reality.

The various chapters of this timely and comprehensive book should give the reader a thorough understanding of the degree to which machine learning methods have percolated into the various layers of the chip design hierarchy. From lithography and physical design to logic and system design, and from circuit performance estimation to manufacturing yield prediction, VLSI CAD researchers have already brought state-of-the-art algorithms from supervised, unsupervised, and statistical learning to bear on pressing CAD problems such as hotspot detection, design-space exploration, efficient test generation, and post-silicon measurement minimization.

Machine learning in VLSI CAD is expected to play an increasingly important role not only in improving the quality of the models used in *individual CAD tools* but also in enhancing the quality of chip designs that result from the execution of entire *CAD flows and methodologies*.

As the semiconductor industry embraces the rising swell of cognitive systems and edge intelligence, this book could serve as a harbinger and an example of the osmosis that will exist between our cognitive structures and methods, on the one hand, and the hardware architectures and technologies that will support them, on the other.

The value proposition of automation is that it compresses schedules, reduces costs, and eliminates human errors. In the case of VLSI CAD, the automation has achieved not only these objectives but also the infinitely more important outcome of a seamless implementation of a positive feedback loop whereby computers are used to design more powerful computers. This positive feedback loop is the invisible hand of Moore's law.

As we transition from the computing era to the cognitive one, it behooves us to remember the success story of VLSI CAD and to earnestly seek the help of the invisible hand so that our future cognitive systems are used to design more powerful cognitive systems. This book is very much aligned with this ongoing transition from computing to cognition, and it is with deep pleasure that I recommend it to all those who are actively engaged in this exciting transformation.

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Dr. Ruchir Puri
IBM Fellow, IBM Watson
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Xin Li received his Ph.D. degree in Electrical and Computer Engineering from Carnegie Mellon University in 2005. He is currently a Professor in the ECE Department at Duke University and is leading the Institute of Applied Physical Sciences and Engineering and the Data Science Research Center at Duke Kunshan University. His research interests include integrated circuit, signal processing, and data analytics. Dr. Li is the Deputy Editor-in-Chief of *IEEE TCAD*. He was an Associate Editor of *IEEE TCAD*, *IEEE TBME*, *ACM TODAES*, *IEEE D& T*, and *IET CPS*. He was the General Chair of ISVLSI and FAC. He received the NSF CAREER Award in 2012 and six Best Paper Awards from IEEE TCAD, DAC, ICCAD, and ISIC. He is a Fellow of IEEE.