

A Review on Impact of AI on VLSI

Aphasana Mulla and Sukeshini Tabhane

Lecturer, Electronics and Telecommunication Engg.
Bharati Vidyapeeth Institute of Technology, Navi Mumbai

Abstract: *The rapid evolution of semiconductor technology has made Very Large-Scale Integration (VLSI) design increasingly complex. Artificial Intelligence (AI) has emerged as a transformative solution for automating and optimizing critical design stages such as synthesis, placement, routing, verification, and testing. By incorporating techniques from machine learning (ML), deep learning (DL), and reinforcement learning (RL), AI enables faster design convergence, improved performance–power–area (PPA) trade-offs, and cost reduction. This paper reviews the key roles, benefits, challenges, and future directions of AI applications in the VLSI design flow.*

Keywords: Artificial Intelligence, Very Large Scale Integration

I. INTRODUCTION

Artificial Intelligence (AI) has entered almost every aspect of life. VLSI design is one of them. VLSI has enabled the production of smaller and more compact devices. We continue to widen the scope of Moore's law. Hence, the complexities associated with designing complex and power-effective VLSI systems have grown exponentially. The incorporation of AI can significantly impact the VLSI, optimizing various stages and enhancing the overall efficiency of the process. For instance, AI can enhance RTL design by automating operations like logic synthesis.

Key impacts of AI on VLSI

- **Automated design tasks:** AI automates and optimizes crucial parts of the design process, including logic synthesis, floor planning, placement, and routing. This reduces the need for extensive manual labor and speeds up design cycles.

Improved design quality:

- **Predictive modeling:** AI uses predictive models, such as neural networks, to estimate design performance before physical implementation, allowing for early identification and correction of potential issues.
- **Optimization:** AI algorithms optimize for key metrics like power, performance, and area (PPA), leading to more efficient and robust chips.
- **Enhanced testing and verification:** AI can improve testing efficiency by learning from past data to identify and suggest solutions for faults, increasing coverage and reducing time-to-market.
- **Data-driven decision-making:** AI excels at analyzing the vast amounts of data generated during the design process to find optimal solutions that might be missed by humans.
- **Architectural innovation:** The integration of AI is enabling the development of new, dynamic VLSI architectures for applications like edge AI, IoT, and signal processing.
- **Shift in engineer roles:** AI is shifting the role of VLSI engineers away from tedious, repetitive tasks toward more strategic activities like high-level architecture, system-level thinking, and AI-driven optimization oversight, according to LinkedIn.

II. LITERATURE SURVEY

The Very Large Scale Integration (VLSI) industry has started adapting the Artificial Intelligence (AI) techniques in design automation as it provides the opportunity to transform the whole chip design methodology. It has been seen that in System-On-Chip (SoC), in order to add ML algorithms to increase its efficiency, there is a need to reduce the existing power consumption of the hardware as well. Hence, this makes AI an integral part of the VLSI industry. With



this in mind, an extensive review has been conducted on various aspects of AI in the field of VLSI. This paper throws light on how AI has marked its way on various subfields of VLSI, namely, analog, digital and physical design. We have also taken into account the recent machine learning and deep learning techniques incorporated in VLSI. [6]

The impressive progress on VLSI technology and the shifting from design of VLSI chips to Ultra Large Scale Integrated ULSI circuit systems made the use of design automation to a necessity. The developments of computer-aided design (CAD) programs (tool) helped significantly to the automation of VLSI design. Each tool were able to solve different stages of task design more effectively. However, by integrating and putting these tools together into one package, the effectiveness and functionality of CAD programs decreased drastically. To overcome the problems at different design stage, the researchers introduced artificial intelligent (AI) techniques in VLSI design automation. AI techniques such as knowledge-based and expert systems, at first try to define the problem and then choose the best solution from the domain of different possible solutions. [7]

III. HOW IS AI LEVERAGING THE VLSI DEVELOPMENT LIFECYCLE?

Design Exploration

AI techniques, such as genetic algorithms and evolutionary learning, can be used to optimize various aspects of VLSI design. Furthermore, AI aids in determining critical paths and how to accomplish less power consumption in VLSI techniques, like frequency scaling and dynamic voltage, can be improved with AI.

Automatic Test Pattern Generation (ATPG)

It is an EDA methodology used to identify an input or test sequence. ATPG validate the correct circuit behaviour and faulty circuit behaviour caused by defects. The patterns obtained are used to test semiconductors. However, the effectiveness of ATPG is a concern. AI can automate the generation of advanced test patterns for design verification.

RTL Design Optimization (RTL)

AI can automate operations, such as datapath optimization, and resource allocation. Hence, helps optimize RTL. ML algorithms can comprehend the design specification, performance goals, etc.

Physical Design Enhancement

AI can help improve physical design operations, such as routing, placement, and floorplanning. Moreover, ML algorithms can optimize chip layout, enhance timing closure, and minimize wavelength. There are other design challenges, like signal integrity analysis and clock tree synthesis, where AI can assist. For instance, the AI algorithm considers the factors skew, and power consumption for clock tree structures.

Fast Design Exploration and Innovation

AI-driven behavioral synthesis tools have introduced high-level abstractions that allow designers to work at a more abstract level, focusing on functionality rather than low-level details. This shift in perspective enables faster design exploration and innovation. Machine learning models can learn from existing designs and propose high-level structures that match desired functionalities. This streamlines the design process and facilitates the exploration of diverse design alternatives, leading to more creative and efficient solutions.

Predictive Modeling and Fault Tolerance:

AI plays a crucial role in predictive modelling for VLSI designs. Predictive models, often based on neural networks, can estimate the performance of a design before it is physically implemented. This capability helps designers identify potential issues early in the design phase, reducing the need for costly redesigns. Moreover, AI contributes to fault tolerance in VLSI designs. By analyzing historical data on failures and learning from them, AI algorithms can suggest design modifications or redundancies to enhance integrated circuits' robustness against various faults.

Analog and Digital Circuit Development

AI is helpful in analog and digital VLSI circuit design. In digital circuit design, AI can aid in logic synthesis and analog circuit design, AI can help in sizing transistors.

The integration of AI into VLSI design has ushered in a new era of innovation and efficiency. From optimizing power consumption to automating complex design processes, AI has become an indispensable tool for semiconductor designers. The synergy between human creativity and AI-driven optimization is propelling VLSI circuit design to new heights, enabling the development of faster, more efficient, and reliable integrated circuits.



IV. ADVANTAGES OF AI IN VLSI

The integration of AI provides several key benefits:

- **Automation of complex tasks**, reducing human intervention.
- **Enhanced PPA optimization**, achieving better trade-offs among performance, power, and area.
- **Reduced design cycle time**, accelerating time-to-market.
- **Improved accuracy** in prediction and analysis.
- **Adaptability**, allowing systems to learn from past designs and continuously improve.

V. CHALLENGES AND LIMITATIONS

Despite its benefits, AI integration faces several obstacles:

- **Data scarcity**: High-quality labeled data is limited due to confidentiality and design diversity.
- **Interpretability**: Understanding AI decisions is essential for debugging and verification.
- **Scalability**: AI models that perform well on small circuits may struggle with large-scale industrial designs.
- **Integration barriers**: Incorporating AI into existing EDA tools requires extensive infrastructure adaptation.
- **Computational overhead**: Training complex models can be resource-intensive.

VI. CONCLUSION

Artificial Intelligence has become a cornerstone technology in the evolution of VLSI design, driving automation, optimization, and innovation across every design phase. From placement and routing to testing and manufacturing, AI techniques have demonstrated their capability to enhance efficiency, accuracy, and performance. Although challenges such as data scarcity and interpretability persist, continuous research and industrial adoption promise a future where AI-driven VLSI design becomes the industry standard.

REFERENCES

- [1]. Mirhoseini et al., "A Graph Placement Methodology for Fast Chip Design," *Nature*, vol. 594, 2021.
- [2]. K. Han and J. Cong, "Machine Learning for Electronic Design Automation: Challenges and Opportunities," *DAC*, 2020.
- [3]. S. Kundu, "AI Applications in VLSI Design Automation," *IEEE Transactions on CAD*, 2022.
- [4]. X. Xu et al., "Deep Reinforcement Learning for Chip Placement," *ICCAD*, 2021.
- [5]. Y. Chen and T. Zhang, "AI for Yield Prediction in Semiconductor Manufacturing," *IEEE Access*, 2023.
- [6]. "Implementation of AI in the field of VLSI: A Review", IEEE, 2022 Second International Conference on Power, Control and Computing Technologies (ICPC2T)
- [7]. "The impact of AI in VLSI design automation," Mohammad Mortazavi Nikolaos Bourbakis

