Integrating AI Into PCB Design Flow

Beyond Design

Feature Column by Barry Olney, IN-CIRCUIT DESIGN PTY LTD / AUSTRALIA
with Special Advisor Charles Pfeil

Today's PCB design tools are a far cry from the rudimentary tools we used 30 years ago, but even though the algorithms are now quite clever, they are still fairly basic as far as intelligence goes. Comprehensive design rules can be established to accommodate myriad constraints to limit placement and routing which advise us when we have overstepped the boundaries. But what if artificial intelligence (AI) was introduced into the mix? How could it enhance the PCB design environment? What would happen if we applied AI/machine learning techniques as part of the design flow?

PCB designers are used to complex designs and much of the design process is a fairly straightforward engineering challenge. However, the number of options and potential interactions has soared. There are many ways to achieve the same goal, but some ways are better than others in the context of system integrity or a specific application. Still, keeping track of all the possible tradeoffs and options in a complex design is approaching technological singularity—the hypothetical point when computer capacity rivals that of a human brain.

Google, Xilinx, Synopsys, Intel, Cadence, and Siemens are all working on AI applications for silicon design. Recently, machine learning (ML)-based techniques have been efficiently utilized in several applications,

where enhanced learning capability makes them unique to solve any complex/nonlinear problem. IC design has also benefited from ML techniques at different design levels, from device modeling to test of manufactured chips. IC layout is a very labor-intensive task that typically requires iteration. The performance of an IC depends on where things sit relative to each other. The distances between objects, the wire length, capacitance, and the inductance of the interconnects are also important. After the initial layout, the simulated values of variables are back-annotated to the design. This first layout may not be perfect, so further iterations are required. Reducing the number of iterations and, hence, the design cycle time by using AI, can be extremely cost-effective.

Much of the same methodology happens with PCB layout: We do a pre-layout simulation to determine the constraints, a post-layout simulation to verify the layout, and then the results are back-annotated. This process can also take many iterations.

Earlier this year, Cadence announced the release of the Allegro X AI cloud technology. Cadence states that it dramatically reduces design turnaround time (10X) by automating placement, power plane generation, and critical net routing. Cadence has been developing place and route (P&R) tools for IC synthesis for decades and has now adapted the technology for PCB P&R. Shorter interconnects and reduced crossovers are essential for both chip and PCB layout but critical routing incorporating signal integrity and flight time requirements is of greater importance for the PCB.

EDA tools will inevitably take much longer to develop.

Unfortunately, most EDA vendors do not have the same resources to pour into R&D as the Big Tech companies. Such financial backing, coupled with creative engineering, reduces time-to-market. So, EDA tools will inevitably take much longer to develop. Then, most EDA companies are primarily interested in doing R&D that increases sales in the next cycle, not long term.

Currently, EDA tools use algorithms to control auto-placement and routing. This is a set of instructions that a computer program follows to accomplish a task. PCB routers have gone through many different stages of development over the years, from third-party applications that were difficult to learn, use, and interface, to a cohesive, cloud-based, layout/router environment. IC and PCB routing applications have used many of the same algorithms over time, including:

- Lee's Algorithm (maze routing)
- Dijkstra's Algorithm (shortest path)
- Grid-based routing
- Rip-up and reroute
- Shape-based, push-and-shove
- Steiner Tree (rectilinear routing)
- Heuristic (topology) routing

It is not so much the algorithms that differ, but rather the environment that dictates which algorithm is most effective.

With the advent of AI, machine learning applies artificial intelligence that provides systems with the ability to automatically learn and improve from experience without being explicitly programmed. This is sort of like how proficient PCB designers know how to best tackle a complex task: Experience is the best teacher of all. These algorithms are procedures that are implemented in code and run-on data. Machine learning models are output by algorithms and are comprised of model data and a prediction algorithm. Machine learning algorithms provide a type of automatic programming where machine learning models repre-

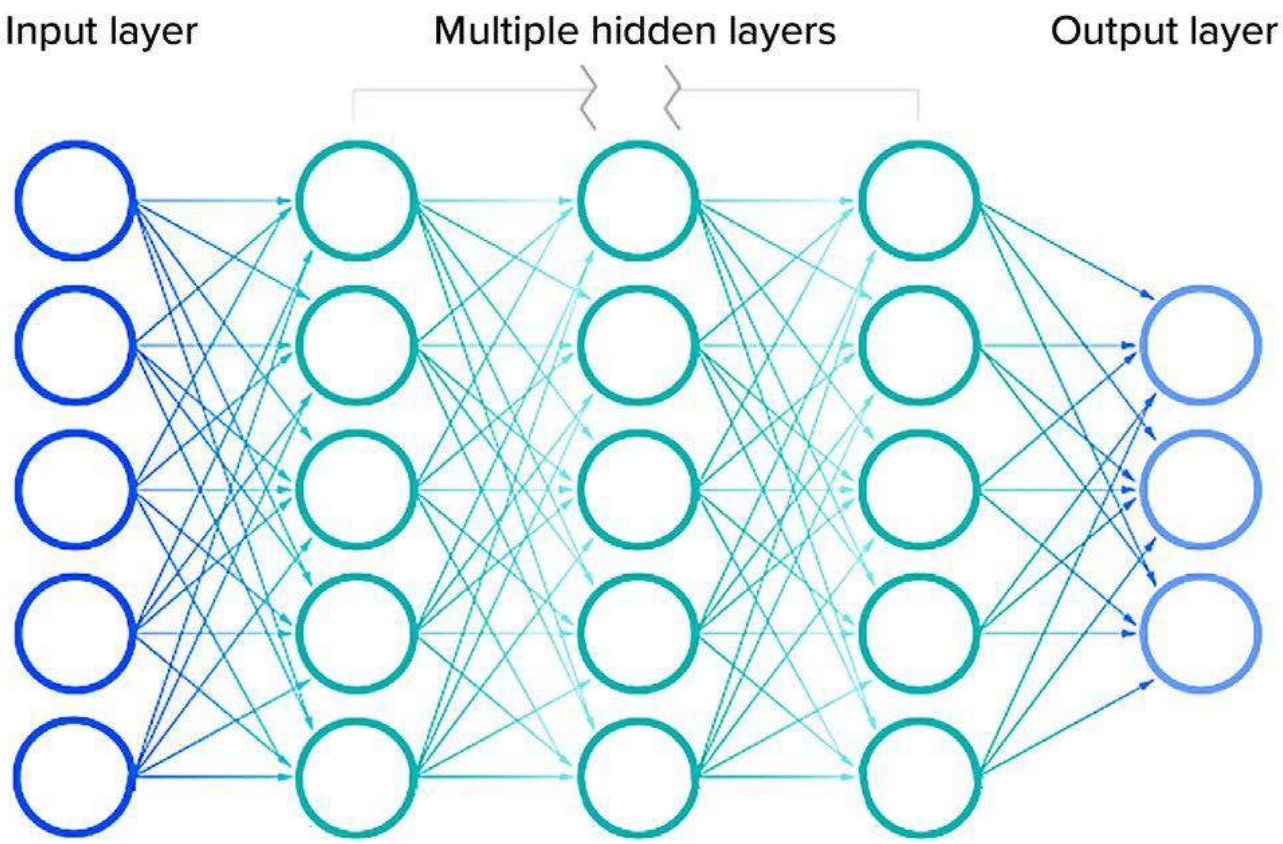


Figure 1: Machine learning model. (Source: IBM)

sent the program. In other words, algorithms are the building blocks that make up machine learning and artificial intelligence.

A machine learning model (Figure 1) is a model that has been trained to recognize certain types of patterns. A model is trained over a set of data, providing it with an algorithm that it can use to reason over and learn from those data. Specifically, machine learning models are computer programs that are used to recognize patterns in data or to make predictions. Machine learning models are created from machine learning algorithms. These algorithms adapt, evolve, and improve themselves based on the data they process. The models can be used to make predictions, categorize information, or discover patterns.

How Could AI Improve Placement and Routing of a PCB?

Skilled PCB designers have many years of experience laying out complex designs such as high-speed FPGA and memory circuits, so AI needs to absorb this same information in order to achieve the same (or better) results but in a much shorter timeframe. Data in the form of design rules and images of preferred routing strategies can be fed into the input layer of the machine learning model. Algorithms in the hidden layers of the model can then process this data, and recognize, predict, and create the resultant layout (Figure 2).

Sample images of steadfast routing patterns plus the netlist, appropriate rules for electrical and mechanical constraints, frequently used stackup configurations, system timing, and memory timing requirements (plus sample eye diagrams of working designs) are fed into the model where the learning algorithms recognize and process the images and data to predict an optimal solution.

Machine learning uses two types of techniques: supervised learning, which trains a model on known input and output data so that

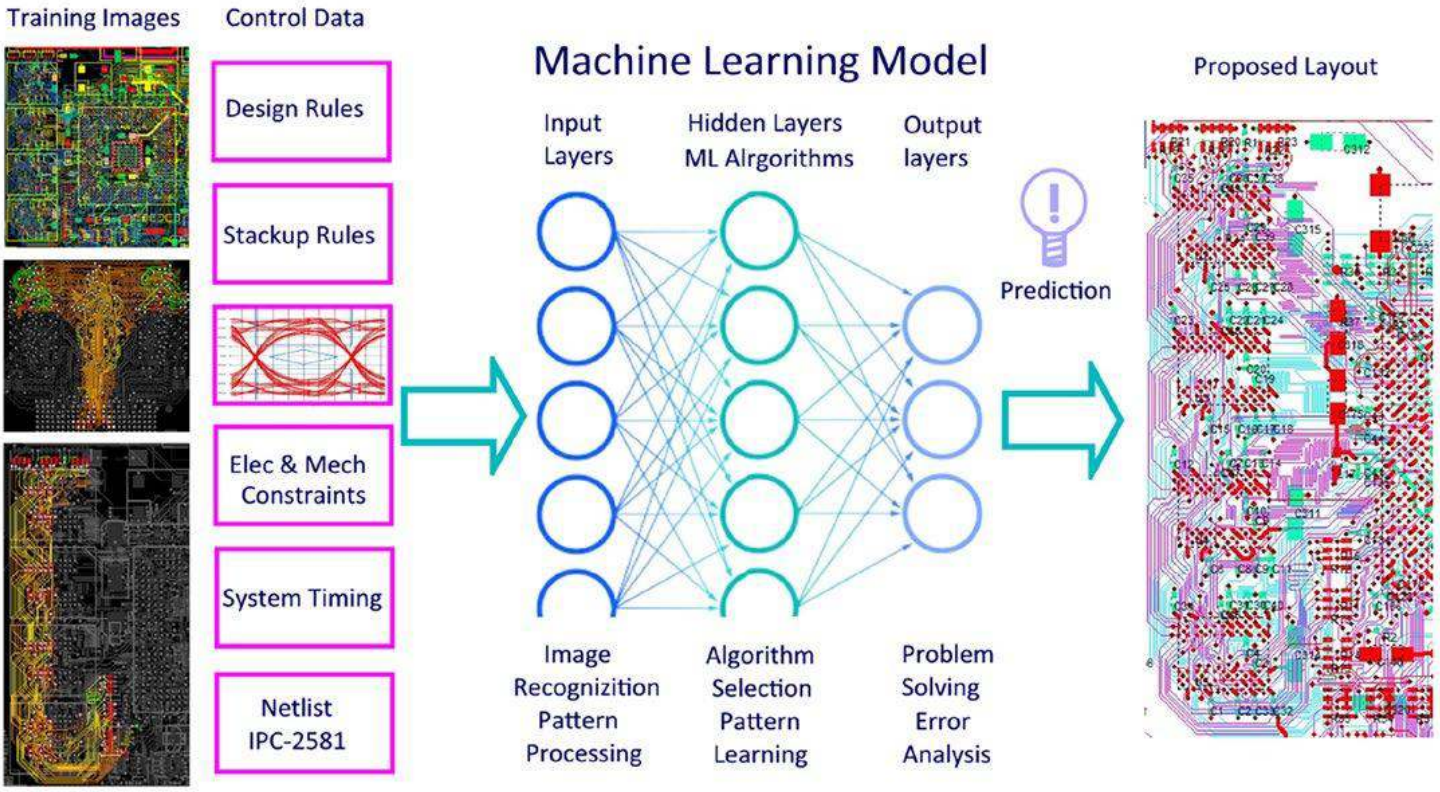


Figure 2: Machine learning model for PCB layout.

it can predict future outputs, and unsupervised learning, which finds hidden patterns or intrinsic structures in input data.

Choosing the right algorithm can seem overwhelming; there are dozens of supervised and unsupervised machine learning algorithms, and each takes a different approach to learning. There is no best method or one size fits all. Finding the right algorithm is partly just trial and error but is also based on the recognition of patterns learned, and experience with similar designs. The algorithm selection also depends on the technology used (e.g., DDR4), frequency, and rise time of the signal.

The biggest issue in training AI with PCB images is the availability of data. ChatGPT had access to the unlimited wealth of information available on the internet, however, PCB models only have access to the images and data fed into the machine learning model which, by comparison, is extremely limited. One way around this would be to create an open-source global repository for PCB layout images and databases that have endorsed functionality. However, convincing customers to share their designs may be difficult as most do not wish to publicly expose their intellectual property.

Key Points

- There are many ways to achieve the same goal, but some ways are better than others in the context of system integrity or a specific application.
- Reducing the number of iterations and, hence, the design cycle time by using AI can be extremely cost-effective.
- Shorter interconnects and reduced crossovers are essential for both chip and PCB layout but critical routing incorporating signal integrity and flight time requirements is of greater importance for the PCB.
- Currently, EDA tools use algorithms to control auto-placement and routing.
- With the advent of AI, machine learning applies artificial intelligence that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.

- Algorithms are the building blocks that make up machine learning and artificial intelligence.
- A machine learning model is a model that has been trained to recognize certain types of patterns.
- AI needs to absorb and learn from information in order to achieve the same (or better) results.
- Finding the right algorithm is partly just trial and error but is also based on the recognition of patterns learned and experience with similar designs. DESIGN007

Resources

- 'Beyond Design: Artificial Intelligence in EDA Tools' by Barry Olney, May 2016, *The PCB Design Magazine*
- "What is artificial intelligence," ibm.com
- "What is Artificial Intelligence," by Alyssa Schroer, May 19, 2023, builtin.com
- "EDA Vendors Widen Use of AI," by Ed Sperling, Sept. 29, 2021, semiengineering.com

Charles Pfeil worked in the PCB industry for more than 50 years as a designer and owner of a service bureau. Now retired, he is the original product architect for Expedition PCB and an inventor of XtremePCB and more recently enhanced the Altium routing technology

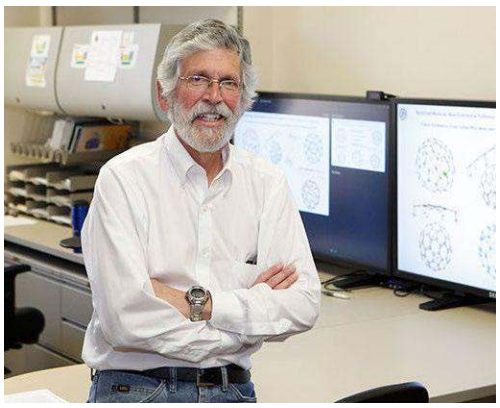
Barry Olney is managing director of In-Circuit Design Pty Ltd (iCD), Australia, a PCB design service bureau that specializes in board-level simulation. The company developed the iCD Design Integrity software incorporating the iCD Stackup, PDN, and CPW Planner. The software can be downloaded at www.icd.com.au. To read past columns, click here.

Researchers Achieve Historic Milestone in Energy Capacity of Supercapacitors

In a new landmark chemistry study, researchers describe how they have achieved the highest level of energy storage in a supercapacitor ever recorded.

Supercapacitors store electrical energy between two metal plates that are close together but separated by a surface that cannot conduct electricity. Supercapacitors are similar to batteries, except that batteries store and retrieve energy using chemical transformations, while capacitors store energy by using oppositely charged surfaces.

"This is a big step forward and gets us closer to achieving supercapacitors with high energy density, which would radically change how we store and manage energy," said Dr. Luis Echegoyen, a longtime faculty member within the University of Texas at El Paso's Department of Chemistry and Biochemistry.

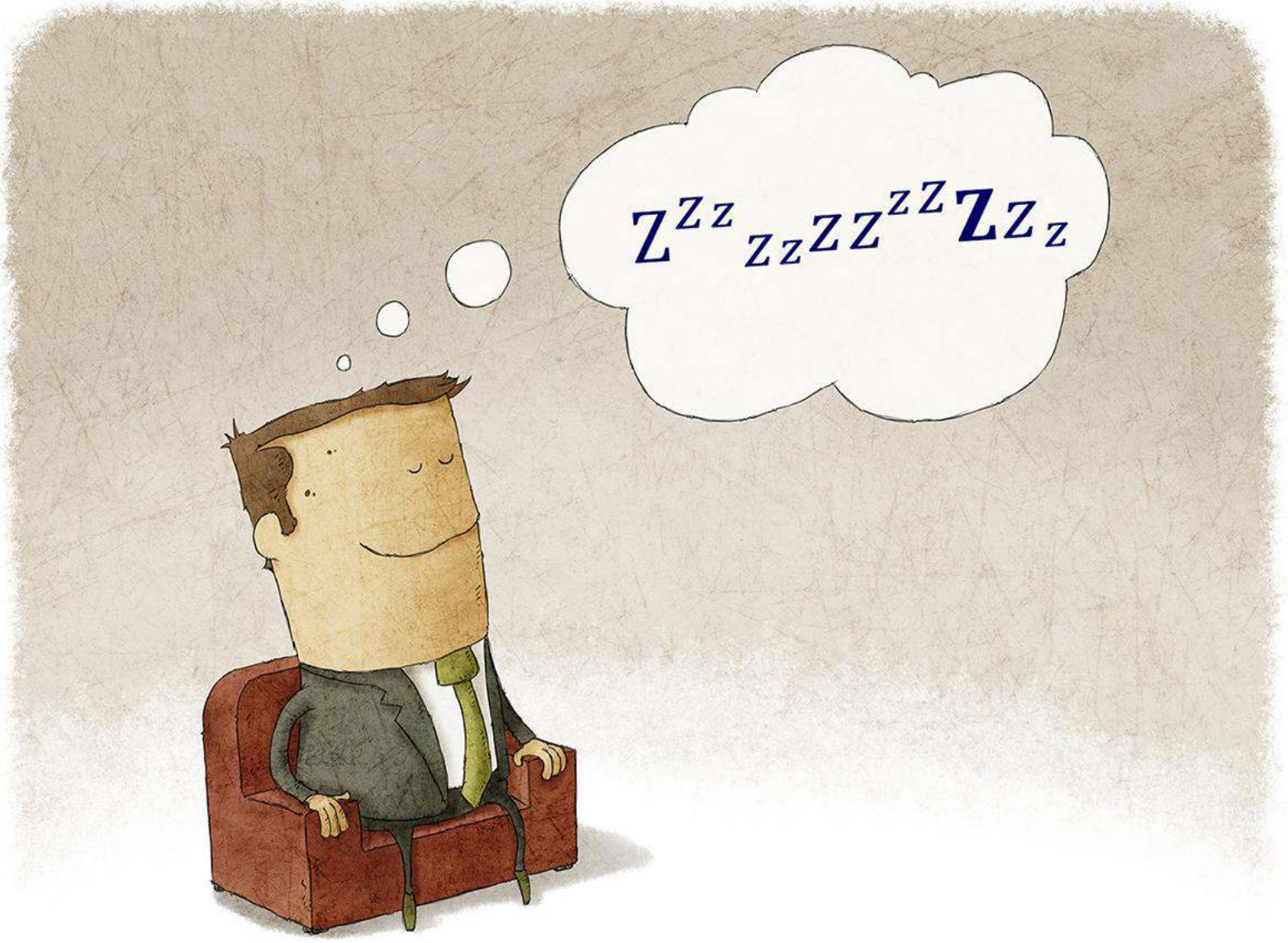


Supercapacitors have high potential because they can charge much faster than batteries—within seconds to fractions of a second, according to Echegoyen. However, current supercapacitors can only store a low amount of energy, which limits their range of potential applications. If supercapacitors could be designed to store more energy, they would be physically lighter and charge much faster than batteries.

The new supercapacitor designed by Echegoyen and Dr. Marta Plonska-Brzezinska of the Medical University of Bialystok achieved a record level of storage, or capacitance, using a material with a carbon "nano-onion" core structure, which creates multiple pores that allow storage of a greater volume of energy.

(Source: University of Texas at El Paso)

We DREAM Impedance!



Did you know that two seemingly unrelated concepts are the foundation of a product's performance and reliability?

- Transmission line impedance and
- Power Distribution Network impedance

DISCOVER MORE

iCD software quickly and accurately analyzes impedance so you can sleep at night.

iCD Design Integrity: Intuitive software for high-speed PCB design.

"iCD Design Integrity software features a myriad of functionality specifically developed for PCB designers."
– Barry Olney

iCD
In-Circuit Design Pty Ltd

www.icd.com.au