Is Life Science the New Frontier of Design Automation?
A 45 year perspective on DA

Alberto Sangiovanni-Vincentelli

The Edgar L. and Harold H. Buttner Chair of EECS
University of California, Berkeley

Co-founder and Member of the Board,
Cadence Design Systems
Agenda

• How did we go from handcrafted designs to a scientific process in EDA?
• The Birth of EDA as we know it today
• The future of classical EDA
• System Level Design
• Back to the Future: Life Sciences and EDA
Once upon a Time... 1971 (when I graduated)

3,500 Transistors, 92K IPS

Verifying the chip

Preparing the masks

Magnetic-core memories

Punched card
Evolution: From Handcraft to...

Intel 4004

Intel 8086

Intel 80286
To... Methodology:
Logic Abstraction, Regularity, Libraries, and Tools!
1983, Intel 386
275,000 Transistors

Industry complexity problems spurred theoretical research that ended up in at least 80 papers, DARPA grants, awards, and

start-ups
How Did We Cope with Complexity?
A Live Person quote!

Abstractic Methodologies Tools
ASV: Freedom from choice
Time to Offload the Ball!
Agenda

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The Origin of Cadence

EDA
The Founding Document

Cadence Design Systems, Inc.

Original Business Plan
July 25, 1983
CONFIDENTIAL

BUSINESS PLAN FOR:

ISIS SYSTEMS, INC.

A NEW CORPORATION IN ELECTRONIC DESIGN AUTOMATION

July 25, 1983

Copy No. S-7
The Basic Tenets: a Complete Methodology

– Framework based on a unified database and graphical user interface
– FIRST software-only company based on Unix workstations,
– Full suite of physical verification (DRC, ERC) and simulation (circuit, logic and mixed)
– Automatic layout for macro cell, standard cell and gate array design styles
– New funding model: mixed VC (4M$) and companies (National, Harris, GE, Ericsson) (6M$)
– Public in 1988
Synopsys:

- Funded in 1987 (DeGeus, Newton, ASV)
- Based on automatic synthesis
- Same funding model as Cadence: VCs and companies (GE, Harris)
- Public in 1991
Coping with Moore’s Law: The Role of Cadence and Synopsys

Feature size (nanometers)

- 100nm
- 10nm
- 1nm

Timeline:
- 1970: Intel 8080
- 1980: Intel 8086
- 1990: Pentium
- 2001: Pentium Pro
- 2003: IA-64
- 2010: Pentium III
- 2020: 1 billion transistors

Technologies:
- Bipolar, NMOS
- CMOS

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DESIGN “PRACTICE”
DESIGN SCIENCE:
Principles not Techniques

Segesta (Σέγεστα) Temple, Sicily, 420 BC
(Picture Taken 2020)
General Principles

• Verification complexity is managed by:
  – **Abstraction**: Reduce the number of items by aggregating objects and by eliminating unnecessary details with respect to the goal at hand
  – **Decomposition**: Reduce the number of items to consider by breaking the design object into semi-independent parts (divide et impera)

• Design complexity is managed by “construction”:
  – **Refinement**: Start high in the abstraction layers and define a number of refinement steps that go from the initial description to the final implementation
  – **Composition**: Assemble designs by composing existing parts
Formalization
Virtual Design and Refinement
Library-based Design Reuse
Plug and Pray!
Today’s Monster Chips: Apple A11 4.3Billion transistors
TESLA FSD SoC

NoC – Network on chip
ISP – Image Signal processing
Safety Sys – Lock step for ISO26262
Security – only TESLA certified software

Chip focused on Automotive L5 use case for Deep learning
Summary: EDA Design Methodology

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Long-Term Trends

- Design Complexity
- More than Moore
- Shift-Left Paradigm
- More Moore
- System Companies Building Silicon
- Digital Transformation
- Domain-Specific Architectures
- 3D-IC

Growth in Semi Content in Systems:
- 2020: $1,650B
- 2021: $1,850B
- 2022F: $1,970B

Computational Software – Transformational Impact

1.0 (EDA) Point tools
Physics based
Inside-out – Engines
Single-threaded
Simulation
Electrical
How are we doing now in core EDA?
Broad Range of Secular Megatrends Driving Growth

Semiconductor Market Expected to Grow to

>$1T

By the End of this Decade
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Semi-automatic transmissions with paddle shift operation were first introduced to control the electro-hydraulic gear shift mechanism of the Ferrari 640 Formula One car in 1989.
Cyber-Physical Systems (CPS):
Interconnect the World Around Us and Make It “Smarter”
Integrated System Design and Analysis
Electronic / mechatronic system complexity exponentially increasing
Accelerating Hyperconvergence => Faster System Realization
Computational Software... Is All About the Underlying Math
Finite Element Method

• The numerical method of choice to solve PDEs
• Discretize PDEs onto Meshes
• PDEs become linear sparse matrix to solve
• Performance/capacity of FEM solver is largely dependent on that of the sparse matrix solver
Distributed Matrix Solver

Root – Dense Matrix

Leaf – Sparse Matrix
### Distributed Matrix Solver
Takes advantage of structure of FEM

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- Performance/capacity of solver heavily depends on quality of partitioning
- Leaf is sparse and Schur complement is dense

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G. Guardabassi and A. Sangiovanni-Vincentelli
A two levels algorithm for tearing,
IEEE Transactions on Circuits and Systems 23 (12), 783-791, 1976

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## Cadence M&A (Since 2019)

<table>
<thead>
<tr>
<th>Company</th>
<th>Domain</th>
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<td>Future Facilities</td>
<td>Datacenter Digital Twin</td>
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<tr>
<td>Pointwise</td>
<td>CFD meshing</td>
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<td>NUMECA</td>
<td>CFD Solutions</td>
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Computational Software – Transforming the Future

1.0 (EDA)
- Point tools
- Physics based
- Inside Out - Engines
- Single threaded
- Simulation
- Electrical

2.0
- Platform play
- Outside In – AI / ML flows
- Massively parallel
- Simulation + Optimization
- Electrical + Mechanical + Thermal
- HW/SW Co-design

Productivity / Automation

Semis

Electronic Systems
Agenda

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• **Computational Biology** is a System Domain with complex physics, modeling and simulation → All core competencies of Cadence

• **Speed Matters**; Cadence Computational methods can drive faster, more complex, simulation → driving industry growth

• **AI and Data Driven Drug Discovery/Design** are expanding fields
EDA and Biology: Personal Fascination

- Vertex Pharmaceuticals was one of the first biotech firms to use an explicit strategy of rational drug design rather than combinatorial chemistry. Greylock was one of the VCs who invested in Vertex.

- 1989 BioCAD, a biotech software company that was the first to apply EDA principles to pharmaceutical discovery (Steve Teig, exiting Cadence after Tangent acquisition)
EDA and Biology: Personal Fascination

• Cadence Research Laboratories established in 1993 in Berkeley to focus on advanced research in electronic design automation, had a research project on Computational Biology


Platform-based Design Environment for Synthetic Biological Systems

Douglas Densmore (EECS, Boston University), J. Christopher Anderson (Bioengineering), Alberto Sangiovanni-Vincentelli (EECS)

• Clotho is a design environment for the creation of biological systems from standardized biological parts.

• Composed of “views”, “connectors”, “interfaces” and “tools”


• Versions available at http://cidarlab.org/software-overview/.
Putting it all together
(Doug Densmore, Boston University)

1. Decide on the general functionality desired.

2. Specify the composition of the devices and the constraints on the system.

3. Design variations of the design, assign theoretical parts to physical samples, modify sequence, etc.

4. Send design to liquid handling robot assembly workflows, capture successes and failures as constraints for future designs, and save created devices.

InduciblePromoter ip("ACTGGT…");
AntiRepressor ar("CATGGT…", "high");
Terminator t("GGTAAC…", 99);
LyticReplicon lr("CTTACC…", 110);

Rule r4a(rp1 NOTWITH lr);
Note(r4a);
Improvements in speed, accuracy and usability of simulations will drive broader adoption and help Pharma to move to a more robust methodology and to a “fail fast, fail cheap” model.
Final Words of Wisdom

Giuseppe Arcimboldo, The Librarian, 1566
Skokloster Castle, Sweden

Giorgio De Chirico, Le Muse Inquietanti, 1917-18
Collezione Mattioli, Milano, Italy
Concluding Remarks

• It has been a long and wonderful journey ... more than 45 years!
• But it is not over ... yet! Much needs to be done...
• PRINCIPLES MUST guide research, NOT techniques
• We need new paradigms to go beyond what we know:
  – Cyber-physical systems, Systems of systems..., Swarm systems
  – Biological Systems
• Education!
By Popular request (Ant):

IS ARTIFICIAL INTELLIGENCE A PANACEA?
Big Data + Processing Power = New Age for Artificial Intelligence

Source: www.cbinsights.com
A Convolutional Neural Network can be fooled...

State-of-the-art DNNs can recognize real images with high confidence.

But DNNs are also easily fooled: images can be produced that are unrecognizable to humans, but DNNs believe with 99.99% certainty are natural objects.

Evolutionary Algorithm

Fitness Evaluation

Mutation

Crossover

Selection

Label and Score

Evolved images

Images from https://web.eecs.berkeley.edu
Bottom line: AI/ML is Glorified Statistics/Approximation Theory
Concerns around AI biases are mounting

AI transparency tech, also known as explainable AI, traces back outputs from AI algorithms to provide a way to understand what’s happening in “human terms.”

As AI is increasingly used for decision-making across industries, understanding how and why an algorithm makes its decisions can help mitigate inherent biases associated with most AI systems in existence today.

What is Explainable AI?

Today

Confusion with Today’s AI Black Box
- Why did you do that?
- Why did you not do that?
- When do you succeed or fail?
- How do I correct an error?

Clear & Transparent Decisions
- I understand why
- I understand why not
- I know why you succeed or fail
- I understand, so I trust you