Can a combination of ML+Formal methods help in automating computer system design?
End of transistor scaling

- Intel 8085, 3 MHz
- Intel Pentium 4, 1.3 Ghz
- Intel dual core, 2.6 GHz
- Power8, 4GHz
End of transistors scaling

General purpose computers not getting any faster!
The Age of Specialisation…

Graphics

Machine learning

Vision

Data centre
Specialisation Problem

* Given a new application domain, how to *specialise* the system stack?
Specialisation Problem

* Given a new application domain, how to specialise the system stack?

**In-Datacenter Performance Analysis of a Tensor Processing Unit™**


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Cost stifling Innovation?

Costs of Latest Nodes Are Skyrocketing

![Cost Breakdown Graph](source: International Business Strategies, T. Austin)
Synthesise computer systems?
Electronic Design Automation

- EDA/High-level Synthesis (Nigel Topham)
  - Successes?
  - Failures?
  - Scope of the problems solved? Limitations?
Computer Systems Synthesis

• Machine learning for Systems

• Iterative compilation

Using Machine Learning to Focus Iterative Optimization

School of Informatics
University of Edinburgh
UK
Computer Systems Synthesis

- Machine learning for Systems @Edinburgh
- Iterative compilation
- Runtime parameter tuning
- Microarchitecture design space exploration
- Benchmark generation
- Source code analysis
Machine Learning for Systems

- What works? What does not?
- What techniques/models to use? (Why?)
- How to select features?
Computer Systems Synthesis?

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Correctness?
Challenge: Correctness

- Correctness a fundamental component of systems
- Bugs are costly!
  - Intel floating point bug, Transaction bug, ARM coherence bug.
- Post-hoc validation expensive!
- Can we have correct by construction?
Systems Synthesis: Formal Methods?

- Given a program specification, and a partial implementation, fill in the rest: Rich history (Edinburgh!)

- PL/Verification community has made tremendous recent progress on program synthesis techniques

- Spreadsheet learning by example, biological models, SQL queries.

- On-going work:
  - Cache coherence protocol synthesis: Correctness
  - Robot controller synthesis: Explainability / guarantees
ML + Formal Methods?

* Synthesise partial implementation (ML) + fill up the result using formal methods?

* Is it essentially a question of how logic and probability can combine?
Computer Systems Synthesis

• The age of specialisation!

• Low cost computer system design key to future innovation

• New techniques: Machine learning + formal methods