Multi-programming

An overview on Parallel Processing with Silicon, Graphics and Quantum Chips

Gahan Saraiya

Firmware Development Engineer
Intel Technology India Pvt Ltd

March 2023

Outline of Talk

Overview of Coverage I

- Basics of Parallel Processing

  Multi-programming, Multi-core Programming
- Computing Core Types
  CPU - Central Processing Unit
  GPU - Graphics Processing Unit

  QPU - Quantum Processing Unit
- Complexity of Solution

  Complexity of implementation with CPU, GPU, QPU
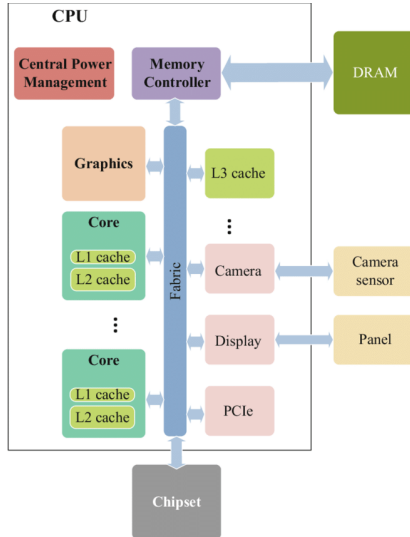- Scalability of Architecture

Outline of Talk

Types of parallel processing

- Single Instruction, Single Data (SISD)
- Multiple Instruction, Single Data (MISD)
- Single Instruction, Multiple Data (SIMD)
- Multiple Instruction, Multiple Data (MIMD)
- Single Program, Multiple Data (SPMD)
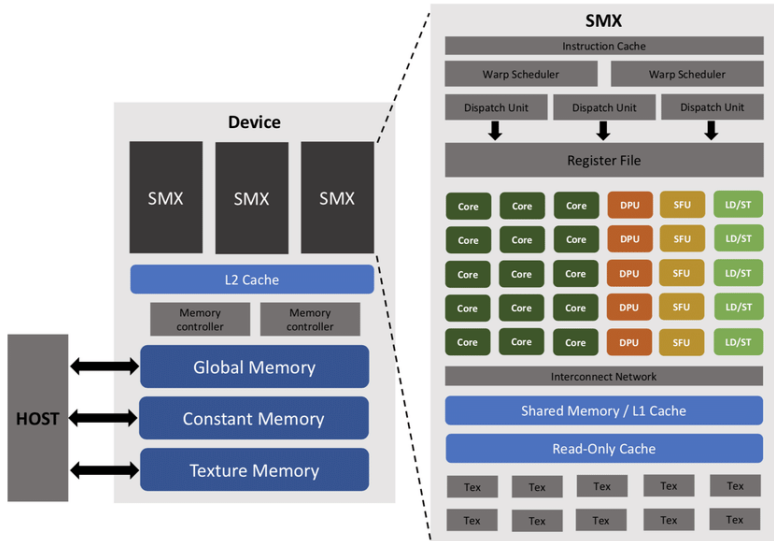- Massively Parallel Processing (MPP)
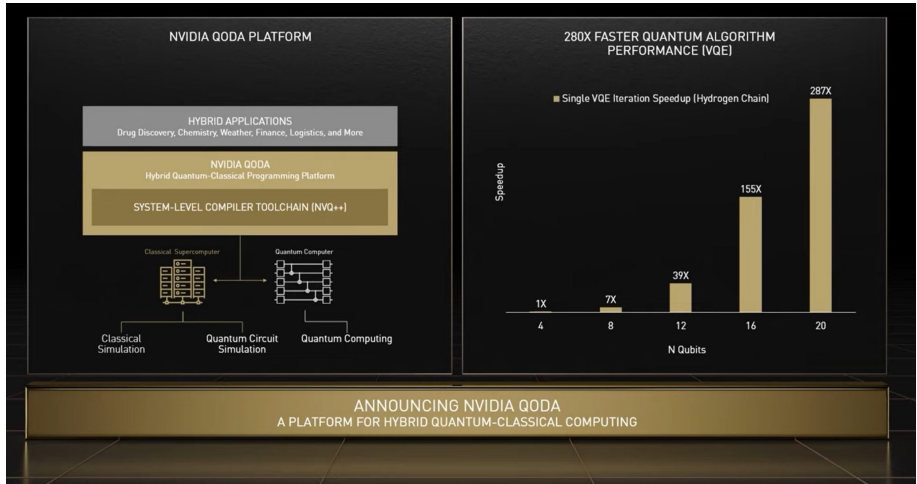
Outline of Talk

CPU - Central Processing Unit

GPU - Graphics Processing Unit I

GPU - Graphics Processing Unit II

QPU - Quantum Processing Unit

Outline of Talk

Applications I

- **Optimization**
    - systems design
    - airline scheduling
    - mission planning
    - financial analysis
    - web search
    - cancer radiotherapy
    - Volkswagen was the first car manufacturer to use a quantum computer to calculate traffic flows.
    - Recruit Communications and D-Wave - collaborated to apply quantum computing to marketing, advertising and communications. (optimize the efficiency of matching advertisements to customers for web advertising.)

Applications II

- **Machine Learning**
    - Improving forecast capability with neural network
    - learn to recognize essences of objects by recognizing patterns in huge amount of data
    - native capability of D-Wave Quantum Processing Unit (QPU)
    - NASA scientists trained the D-Wave 2X system on image data sets in a generative unsupervised learning

Applications III

- **Biomedical Simulations**
    - simulate molecular structures
    - Using D-wave One quantum computer researchers from Harvard University solved the puzzle of how some proteins fold in year 2012
- **Financial Services**
    - complex financial modeling and risk management within the financial industry
    - new ways to model financial data
    - isolate primary global risk factors

Top Quantum Computing Companies I

- **D-wave Systems**
  World's first Quantum Computing Company

  integrates new discoveries in physics, engineering, manufacturing and computer science

  into computational breakthrough approaches to solve most complex challenges.

- **IBM Quantum Computing**
  Offers quantum experience on cloud-enabled quantum computing platform

  allows user to run algorithms, experiments, work on qubits, simulation etc.

- **Microsoft Quantum Computing**

  Conducts theoretical and experimental approaches to creating quantum computers

- **Google Research**
  Quantum Artificial Intelligence Lab - joint initiative of NASA, Universities Space Research Association and Google Research
  goal - how quantum computing help with machine learning and other complex problems of computer science

  Lab hosted at NASA's Ames Research Center

Top Quantum Computing Companies II

- Toshiba Quantum Information Group
  Research teams on Quantum Information, Speech Technology and Computer Vision.
  Collaboration with Cavendish Laboratory and Engineering Department of the University,
  Cambridge and Toshiba R&D groups.

- Intel
  10 year collaboration with institute QuTech, Netherlands formed in 2013 by Delft
  University of Technology for Applied Research in Quantum Computers

- Alibaba Quantum Computing Laboratory
  goal - bring study and applications to the next level, platform for connectivity, computing
  and information security

- Cambridge Quantum Computing
  independent company - expertise in Quantum Information Processing, AI, Optimization
  and pattern recognition

Top Quantum Computing Companies III

- And many more...
  HP Lab : Quantum Information Processing, 1QB Information Technologies, Lockheed
  Martin, Regetti, IONQ, QxBranch, Post-Quantum, ID Quantique, QuintessenceLabs,
  Quantum Biosystems

Types of Quantum Processor

Silicon Spin Qubits

Electrons or nuclear spins on a solid subtract

Superconducting Circuits

currents superposition around superconductor

Ion's Trap

Trap ions in electric fields

Photonic Circuits

qubits are photons driven in silicon circuits

Timeline

May, 2011	D-Wave One (Ranier)	128qb
2013	D-Wave Two	512 qb
2015	D-Wave 2X	1152 qb
2016	IBM Q Experience 5	5qb
2017	Google	20 qb
2017	D-Wave 2000Q	2000 qb
May, 2017	IBM Q 16	16 qb
May, 2017	IBM Q 17	17 qb
October, 2017	Intel 17-Qubit Superconducting Test Chip	17 qb
November, 2017	IBM Q 20	20 qb
2017	Rigetti 19Q	19 qb
January 2018	Intel Tangle Lake	49 qb
March 2018	Google Bristlecone	72 qb

Google AI Quantum I

Superconducting qubit processors

Superconducting qubits with chip-based scalable architecture targeting two-qubit gate error < 0.5%. Google's Bristlecone is newest 72-qubit quantum processor[a].

---

[a]as on 2018

Qubit metrology

Reducing two-qubit loss below 0.2% is critical for error correction. Working on a quantum supremacy experiment, to approximately sample a quantum circuit beyond the capabilities of state-of-the-art classical computers and algorithms.

Google AI Quantum II

Quantum simulation

Simulation of physical systems is among the most anticipated applications of quantum computing.
quantum algorithms for modelling systems of interacting electrons with applications in chemistry and materials science.

Quantum neural networks

a framework to implement a quantum neural network on near-term processors.
understanding advantages may arise from generate massive superposition states during operation of the network.

Google AI Quantum III

Quantum assisted optimization

Developing hybrid quantum-classical solvers for approximate optimization.
Thermal jumps in classical algorithms to overcome energy barriers could be enhanced by invoking quantum updates.
Particular interested in coherent population transfer.