

Future Computing Technologies The Holy Grail of Parallelism

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Outline

- 1 Introduction
- 2 PRAM on a Chip
- 3 Quantum Computing

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Two Crazy Ideas Whose Time Has Come?

- The Game is over for sequential computing (Intel Press Release, March 2005)

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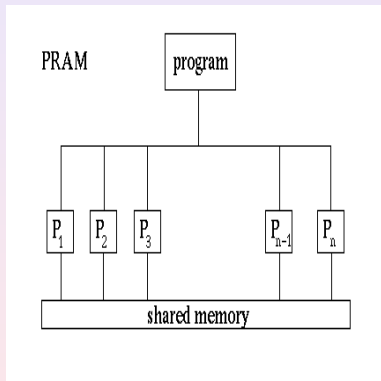
- PRAM
- Quantum Computing

PRAM: Universal Parallel Computation

- Multiple processors
- Common memory
- ... i.e. a **multicore processor!**

Many versions:

- EREW
- CREW
- CRCW

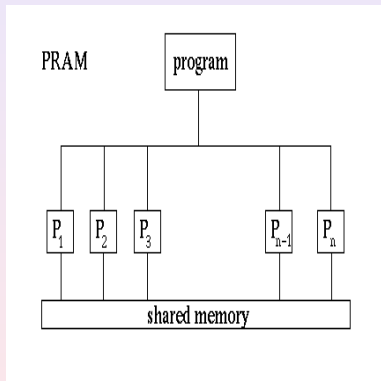


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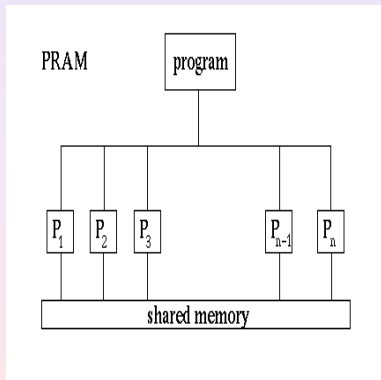


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A PRAM Algorithm

- Given: all airports and all non-stop flights.
- Find: smallest number of flights to get to any other airport from GBG.

PRAM algorithm:

- **Parallel** step i : Give all airports that require $i - 1$ steps, find all that require i steps.

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The Rise of the PRAM

J. Ja Ja, **Introduction to Parallel Algorithms** (1992)

- Lists and Trees.
- Searching, Merging Sorting
- Graphs
- Computational Geometry
- Strings
- Arithmetic Computations

... and the Fall

- The “log-* revolution”: misuse of the model for surreal algorithms running in time $\log^* n$ (= number of times you need to take logs to get down to 1)
- Bandwidth between multichip multiprocessors too limited.

Together contributed to the view that the PRAM is **way too unrealistic** for technologies.

Revenge of the PRAM

- **PRAM-on-a-Chip** (Uzi Vishkin group at UMIACS Maryland)
- Exploit **better bandwidth and latencies** on a chip!

The Three-fold Way

- 1 Design the algorithm conceptually on a PRAM
- 2 Describe algorithm in a high level programming language
e.g. data-parallel Haskell ...
- 3 Map the program onto the OS, hardware ...

Note that this is different from

- 1 Design the algorithm sequentially.
- 2 Parallelize the algorithm....
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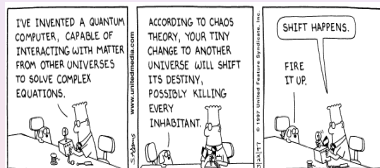
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Parallelism via Quantum Superposition

- A quantum system can be in a **superposition** of many basis states:

$$|\psi\rangle = \sum_i c_i |a_i\rangle.$$

- A **qubit** is a superposition of basis bit states.
- Computation corresponds to unitary operations on such qubits i.e. a parallel processing of the constituent bits. (**Feynman** 1982)



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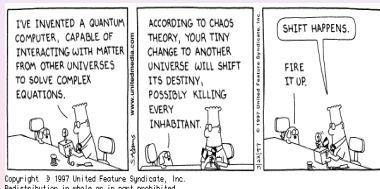
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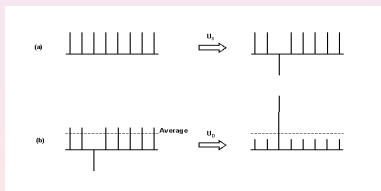


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Two Breakthrough Algorithms

- 1994 **Shor's Factoring Algorithm**: Polynomial time solvable, believed hard on classical model and basis for many cryptosystems such as **RSA**.
- 1996 **Grover's Search Algorithm** Quadratic speedup for searching unstructured domains (searches an unstructured domain of size n in time $O(\sqrt{n})$)



Quantum Algorithms Today

- Shor's factoring
- Fast Fourier Transform.
- Grover's search.
- Quantum random walk.
- Connectivity
- Matching ...

Even in introductory Algorithms textbook:

S. Dasgupta, C. Papadimitriou and U. Vazirani. **Algorithms**
McGraw Hill 2007.

Quantum Programming Languages

Another talk!

Quantum Computers



Next talk!