Low-Energy Computing for Implantable Medical Devices

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Low-Energy Computing for
Implantable Medical Devices

Overview

- Reversible Adiabatic Circuit Technology.
  - The MIT Reversible Computing Project
- Tradeoffs for Low-Energy Circuits.
- General applications.
- Medical Implants - general issues.
- Discussion: Particular implant applications.

General Principles of Adiabatic Circuits

Koller & Athas '92, Younis & Knight '94.

- "Quasistatic" (gradual) voltage changes only.
- Don't connect wires having unequal voltages.
- Must know a wire's voltage in order to change it.
- Voltage information can never be discarded.
- All operations must be logically reversible.

Some Principles of Reversible Computation

Bennett ’73, ’88, ’89. Fredkin & Toffoli ’82.

- As powerful as normal computation.
- Naive implementation consumes memory linearly.
- Can be restricted to less, e.g. logarithmic memory consumption.

MIT Reversible Computing Project

- Adiabatic circuits demonstrated (Younis ′94).
- Instruction set architecture designed (Vieri ′95).
- Work in progress:
  - Detailed logic design of CPU (Vieri)
  - Programming techniques & languages (Frank)
- Future work:
  - CPU circuit layout & testing.
- Goal: have a small working CPU in <3 years.

Reversible Adiabatic Computing
Technological Tradeoffs

- Several times larger circuit area.
- Decreased clock speed.
  - Proportional to energy savings.
- Memory use vs. run time.
  - Logarithmic memory: Polynomial slowdown.
  - Can avoid slowdown w. small energy use.
- Factors affecting total amount of computation possible:
  - Energy available.
  - Memory available.
  - Algorithms used.

Low-Energy Computing

General Applications

- High-density cooling-limited circuits.
- Energy-limited environments.
  - Space, undersea, underground.
  - Portable PCs.
  - Medical implants. ***

Medical Implants—General Issues

- Ratio of computation to sensing/effecting should be large.
- Data-gathering issues.
  - Energy cost of sensing.
  - Computation for data compression/summarizing.
  - External communication.
- Control issues.
  - Computation for planning/decision-making.
  - Energy cost of action.
  - Emitting drugs, electrical impulses: Danger!
- Legal/ethical concerns.

Discussion Topic: Particular Implant Applications

Some naive ideas:

- Blood-monitoring implant for diabetics.
  - Emergency insulin release?
- Smart pacemaker.
- Nervous system interfaces:
  - Artificial retina.
  - Replace damaged nerves/ganglia.
  - Seizure suppression.

Audience: Comments, Other Ideas?

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Summary

- Computing with arbitrarily little energy is possible.
- The emergence of working low-energy reversible CPU's is near.
- Big concern: search for appropriate applications.
- Low-energy computing might be useful in medical implants.
- Some cool ideas for particular medical applications are ...
  - (Insert Your Ideas Here!)