Emerging Models & Technology

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Univ. of Michigan
Program Director
Emerging Models & Technologies
Computing & Communications Foundations
CISE Directorate
National Science Foundation

CCF Division Research Clusters
1. Theoretical Foundations
2. Foundations of Computing
   Processes and Artifacts
3. Emerging Models and Technologies
   for Computation (11th Floor, 1115)

Emergence is "Symbiosis" of Multiple Disciplines of Study

Computer & Information Science & Engineering (CISE) is Central at many Emergent Fields of Research & Education

Quantum Information Science (QIS)
Quantum Physics
Emerging Technologies for Computing Cluster
Consists of 3 Program elements:
QIS, NANO, BIO -- BIC & Comp. Biology

EMERGENCE

Symbiosis

Chemistry

Biological Science

Biology

Biologically Inspired Computing (BIC)

Computational Biology (CB)

Molecular & DNA Computing (NANO)

Biological Computation
Neuro-Cognition
Bayesian Networks
Bio-social Organization
Genome & Genetics
Proteins
Neurons
Tissues, Membranes & Organs
Computation by Tissue Patterns
Gene & Protein Computation

Taxonomy in Computational Biology

Evolutionary Computation
(Survival of the Fittest)
Genetic Programming
Genetic Algorithms
Artificial Immune Systems
Membrane
Artificial Intelligence
Swarm
Social Systems
Cellular Neural Networks
Hopfield Networks
Multilayer Perceptrons
Self-healing, Self-repairable VLSI Chips
Mazumder '89

Nanoarchitectures
Self-assembled Quantum Dot Array
for image processing & video motion detection.

Mazumder '04-08

Self-healing, Self-repairable VLSI Chips

Genetic Programming
Genetic Algorithms
Grammatical Evolution
VLSI Cell Placement
Chip Wire Routing
Chip Floorplanning
Chip Testing
Logic Synthesis

Mazumder '88-94

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From in-Silico To in-Vivo Computing

APPLICATIONS

- Drug manufacturing
- Biomaterial manufacturing
- Nanomachine assembly
- Sensor/effector arrays
- Programmed therapeutics
- Tools for studying genetic regulatory networks

The Others

Computers

©

STATUS OF QUANTUM COMPUTING

The D/Vincenzo Criteria

<table>
<thead>
<tr>
<th>QC Approach</th>
<th>Quantum Computation</th>
<th>QC Relevance</th>
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<tbody>
<tr>
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Speed, Density, Cost and Power Consumption

How Emerging Technologies Compare:

- Speed
- Density
- Cost
- Power Consumption

Quantum Computation is Powerful

Quantum Algorithms

- NP COMPLETE
- 3 SAT
- Graph Isomorphism
- Factoring
- Multiplication

NP

BQP

BPP

P
### Quantum Information Processing

<table>
<thead>
<tr>
<th>Year</th>
<th>Funding Amount</th>
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<tbody>
<tr>
<td>2004</td>
<td>$637,674</td>
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<td>2005</td>
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<td>2007</td>
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### Quantum Hardware

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<td>2007</td>
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### Quantum Communications, Error Correction

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### Quantum Theoretical Modeling

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### Quantum Measurements

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<td>$7.86 M</td>
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### TOTAL (APX.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Funding Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>$2,125,069</td>
</tr>
<tr>
<td>2005</td>
<td>$3,801,000</td>
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<td>2006</td>
<td>$2,810,000</td>
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<td>TOTAL</td>
<td>$15,000</td>
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### Exponential Economic Growth

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<th>Year</th>
<th>Technology</th>
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<td>1971</td>
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<td>1974</td>
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<td>1993</td>
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</tr>
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</table>

### Quantum Computing

- **Opportunities**
  - Quantum Computing Offers ~ 10,000 Speed Advantages over CMOS, CNT, QD, NW, SET, ... QC is likened with Mount Everest (29,000 ft.), while CMOS, CNT, ... are at its Foothill (19,000 ft.).

- **Challenges**
  - No bridging technologies to interface QC cannot be used as Ultra Processor like Super Computers (Cray, Fujitsu FACOM, ...) interface with Main Computers.

- Quantum Computers are ~ 100,000 more expensive than Pentium Chips QC will not enter mass PC/PDA/Notebook market for several billions of people.

- Quantum Computers are suited for Application Specific Complex Scientific Tasks. However, QCs need I/O support to interface with the Surrounding Environment. (Measurement & Sensing of QC’s should be High Priority in Research).

- Ultimately, Quantum Computers in some form will prove that God indeed plays with dice to solve intractable problems and have fun! Einstein was wrong.
Nanoelectronic Devices Beyond CMOS

- carbon nanotubes
- graphene
- flexible electronics
- bio-sensors
- spin torque devices
- nanowires
- molecular electronics

DNA Nanotechnology

2D DNA Self-Assembly