A Bio-Inspired and Scalable Computing: Communication Systems and More in the era of Big Data

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Prelim. parts of this lecture have been presented as keynotes at: IEEE BIBE (Harvard Univ., Medical Sch.); OGF (Open Grid Forum, Korea); IEEE HPCC (China); IEEE ICPADS (Australia); IEEE/ACM FGCN (Hainan/China); & as Distinguished Lecture (USA, Canada, Spain, Iran, Saudi, UK)
Organization of the talk:

- Reconfigurable Multi-Ring Network
- Mammography – Detection of abnormalities
- Mammography – Stereocorrelation
Parallelization Approaches For Imaging Operations

- Image-Parallelism
- Data-Parallelism
- Process-Parallelism
- IDP-Parallelism

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A single ring of nodes:

+ More cost-effective than systolic array, tree, exchange, …
+ Each node requires only two links to other nodes (irrespective of the size of the network).
+ Truly scalable.
+ Inexpensive to build.

– Inefficient internode communication between nodes that are not neighbors.
– Inefficient broadcasting at interconnection level.

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A 16-node System

There exists 5 numerically balanced rings:
Reconfigurable MultiRing Network (RMRN)

- A $2^n$ -node ring-based system.

- Reconfigurable into $n+1$ different configurations: $2^{n-s}$ rings each having $2^s$ nodes ($0 \leq s \leq n$). The rings form a torus.

- Scalable (max. no. of active links per node is 4).

- Provides efficient broadcasting mechanisms at interconnection level.

- Provides, as its subsets, many well known topologies.

- More general than the n-cube network???
Reconfigurable MultiRing Network (RMRN)

Consider a ring of $t$ nodes. In order to construct $R$ rings of $D$ nodes each ($R \times D = t$), two extra links for each node, $P_i$, need to be added to the network; they can be found by:

\[
P_i \leftrightarrow P_{(i + R) \mod t}
\]

\[
P_i \leftrightarrow P_{(i + t - R) \mod t}
\]

Example:

Construction of a 16-node MultiRing
The n-Cube Within The MultiRing Network

The 4 single-stage topologies of a 16-node MultiRing.

The 4 single-stage topologies of hypercube of dimension 4
Simple Broadcasting:

1 ring of 8 processors

2 rings of 4 processors each

4 rings of 2 processors each
Broadcasting Mechanisms

Image Tile Broadcasting:

(a) 1 ring of 8 processors

(b) 2 rings of 4 processors each

(c) 4 rings of 2 processors each
Broadcasting Mechanism

Gossiping:

1 ring of 8 processors

2 rings of 4 processors each

4 rings of 2 processors each
A Simple Vision Application

Recognition of useful features from a sequence of digitized images captured from the same scene at different times.

- Conventional Approach (two phases: preprocessing & recognition)

- Utilizing the MultiRing (two phases: preprocessing & recognition)
Mammography – Background

- Breast cancer – 29% of all cancers in women.
- Causes of breast cancer – not clear.
- Detection of breast cancer – methods: Breast self examination, physical examination, mammography and ultrasound.
- Diagnosis of breast cancer – biopsy.
What is Mammography?

- X-ray technique used to examine the breast.
- X-Ray pictures (radiographs/mammograms) show signs of abnormality (benign and malignant processes).
- Mammograms help detect signs of abnormality before they can be palpated.

Problem:
Films require a high degree of skill to read.
The process is very subjective.

Mass Examination:
Reduces overall mortality.
In most cases, one view is sufficient.
Project Objective

- To develop software tools for radiologists who read mammograms (digital mammography).

Anatomically derived principles:

- Mammograms in younger women are brighter than older women.
- Classification (based on tissue density):
  1. Fatty
  2. Fatty-glandular
  3. Dense-glandular
well-defined mass

ill-defined mass

spiculate mass

architecture distortion

microcalcifications
Stereocorrelation
Triangulation

The Matching Process

intensity value is inversely proportional to:
\[ \sqrt{(x' - x)^2 + (y' - y)^2} \]
### A Simple Matching Process

<table>
<thead>
<tr>
<th></th>
<th>Left Image</th>
<th>Right Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 2 4 3 1 5 0 4</td>
<td>0 6 1 3 1 4 5 1 4</td>
</tr>
<tr>
<td>1</td>
<td>2 6 1 6 7 1 6 9</td>
<td>1 4 1 2 1 1 6 1 3</td>
</tr>
<tr>
<td>2</td>
<td>3 1 3 4 1 1 2 2</td>
<td>2 1 5 6 7 1 6 1 7</td>
</tr>
<tr>
<td>3</td>
<td>4 3 1 7 6 6 2 2</td>
<td>3 4 3 2 1 5 4 3 4</td>
</tr>
<tr>
<td>4</td>
<td>5 5 6 1 4 5 6 7</td>
<td>4 1 6 6 7 1 9 1 1</td>
</tr>
<tr>
<td>5</td>
<td>6 2 1 7 6 6 6 1</td>
<td>5 6 1 1 2 3 4 1 5</td>
</tr>
<tr>
<td>6</td>
<td>9 9 8 1 8 1 2 3</td>
<td>6 1 6 1 5 4 1 6 1</td>
</tr>
</tbody>
</table>

(Correlation Window = 3x3)  
(Search Window = 6x4)

1. $\Rightarrow |(1 - 6)| + |(2 - 1)| + |(4 - 3)| + |(2 - 4)| + |(6 - 1)|$
   $+ |(1 - 2)| + |(3 - 1)| + |(1 - 5)| + |(3 - 6)| = 24$

2. $\Rightarrow |(1 - 1)| + |(2 - 3)| + |(4 - 1)| + |(2 - 1)| + |(6 - 2)|$
   $+ |(1 - 1)| + |(3 - 5)| + |(1 - 6)| + |(3 - 7)| = 20$

3. $\Rightarrow |(1 - 3)| + |(2 - 1)| + |(4 - 4)| + |(2 - 2)| + |(6 - 1)|$
   $+ |(1 - 1)| + |(3 - 6)| + |(1 - 7)| + |(3 - 1)| = 19$

4. $\Rightarrow |(1 - 1)| + |(2 - 4)| + |(4 - 5)| + |(2 - 1)| + |(6 - 1)|$
   $+ |(1 - 6)| + |(3 - 7)| + |(1 - 1)| + |(3 - 6)| = 21$

5. $\Rightarrow |(1 - 4)| + |(2 - 1)| + |(4 - 2)| + |(2 - 1)| + |(6 - 5)|$
   $+ |(1 - 6)| + |(3 - 4)| + |(1 - 3)| + |(3 - 2)| = 17$

6. $\Rightarrow |(1 - 1)| + |(2 - 2)| + |(4 - 1)| + |(2 - 5)| + |(6 - 6)|$
   $+ |(1 - 7)| + |(3 - 3)| + |(1 - 2)| + |(3 - 1)| = 15$

7. $\Rightarrow |(1 - 2)| + |(2 - 1)| + |(4 - 1)| + |(2 - 6)| + |(6 - 7)|$
   $+ |(1 - 1)| + |(3 - 2)| + |(1 - 1)| + |(3 - 5)| = 13$

8. $\Rightarrow |(1 - 1)| + |(2 - 1)| + |(4 - 6)| + |(2 - 7)| + |(6 - 1)|$
   $+ |(1 - 6)| + |(3 - 1)| + |(1 - 5)| + |(3 - 4)| = 25$
Number of Operations Per Pixel =

\[ \frac{C^2 \cdot (M - C \div 2) \cdot (N - C \div 2)}{2} \]

Where the Correlation Window size is \( C \times C \) and Search Window size is \( M \times N \).

If \( C = 11 \), \( M = 50 \), and \( N = 22 \) then 92,565 arithmetic operations would be required per pixel!
Some Results
Simple Implementations

- Sun Ultra 40 M2 Workstation – Serial implementation (2 Dual-Core AMD Opteron Model 222SE + 4 GB + Solaris) Implemented in C++.  
  
  *Execution Time: 480 minutes (8 hours).*

- MasPar MP2 (2,048 PE’s)  
  Implemented in a modified C.  
  
  *Execution Time: just over 4 minutes.*

- Sun Ultra 40 M2 Workstation – Serial implementation (2 Dual-Core AMD Opteron Model 222SE + 4 GB + Solaris) Implemented in C++ but operating only around and on edge of the images.  
  
  *Execution Time: 40 minutes.*
PVM/MPI Implementation

Distributed version of the Simple Implementation:

• Apply the operation only around and on the edges of the images.
• Decompose the images into N tiles (overlapping tiles) where N is the number of workstations in the network. In this example, N is 4.

Computer A: Sun Ultra 40 M2 Workstation
(2 Dual-Core AMD Opteron Model 222SE + 4 GB + Solaris).

Computer B: Sun Ultra 40 M2 Workstation
(1 Dual-Core AMD Opteron Model 2214 + 1 GB + Solaris).

Computer C: Sun Ultra 20 M2 Workstation
(1 Dual-Core AMD Opteron Model 1214 + 1 GB + Solaris).

Computer D: Sun Ultra 20 M2 Workstation
(1 Dual-Core AMD Opteron Model 1210 + 512 MB + Solaris).

Execution Time: 18 minutes
PVM/MPI – Farming Implementation

Distributed version of the Simple Implementation

1. The two input images are decomposed into M image tiles each, where M is greater than the number of computers available;
2. Send N of the M pairs of image tiles to the N free computers in the network; when a computer finishes its task, it will send its result to the host;
3. As soon as the host receives a result from a computer, it will then send a pair of image tiles to that computer;

The host continues sending pairs of image tiles to free computes until all tiles have been processed.

<table>
<thead>
<tr>
<th>Tiles</th>
<th>Tile size (pixels)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>128 X 512</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>17.7</td>
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<td>8</td>
<td>64 X 512</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>15.5</td>
</tr>
<tr>
<td>16</td>
<td>32 X 512</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>12.7</td>
</tr>
<tr>
<td>32</td>
<td>16 X 512</td>
<td>24</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>11.0</td>
</tr>
<tr>
<td>64</td>
<td>8 X 512</td>
<td>47</td>
<td>7</td>
<td>6</td>
<td>4</td>
<td>10.5</td>
</tr>
<tr>
<td>128</td>
<td>4 X 512</td>
<td>94</td>
<td>13</td>
<td>11</td>
<td>10</td>
<td>9.3</td>
</tr>
<tr>
<td>256</td>
<td>2 X 512</td>
<td>176</td>
<td>33</td>
<td>26</td>
<td>21</td>
<td>9.0</td>
</tr>
<tr>
<td>512</td>
<td>1 X 512</td>
<td>285</td>
<td>94</td>
<td>70</td>
<td>63</td>
<td>8.7</td>
</tr>
<tr>
<td>1024</td>
<td>1 X 256</td>
<td>561</td>
<td>182</td>
<td>151</td>
<td>130</td>
<td>8.9</td>
</tr>
</tbody>
</table>
Future
Heart – Based Communication Strategy Using MultiRing

1 Ring Topology

- Time Slice = 4.5 Units
- Average Communication Load = 100K Units
Heart – Based Communication Strategy Using MultiRing

- Time Slice = 4.5 Units
- Average Communication Load = 200K Units

2 Rings of 8 Topology

Communication Load

Timeline
Heart – Based Communication Strategy Using MultiRing

- Average Communication Load = 300K Units
- Time Slice = 4.5 Units

4 Rings of 4 Topology

Timeline
Heart – Based Communication Strategy Using MultiRing

- Time Slice = 4.5 Units
- Average Communication Load = 400K Units
Heart – Based Communication Strategy Using MultiRing

1 Ring Topology

- Average Communication Load = 500K Units
- Time Slice = 4.5 Units
Heart – Based Communication Strategy Using MultiRing

Alert!

• Too Much Communication Load for Time Slice of 4.5 Units

• Change Time Slice to 9.0 units
Heart – Based Communication Strategy Using MultiRing

- Average Communication Load = 600K Units
- Time Slice = 9.0 Units
Heart – Based Communication Strategy Using MultiRing

- Average Communication Load = 700K Units
- Time Slice = 9.0 Units
Heart – Based Communication Strategy Using MultiRing

- **Average Communication Load**
  - = 800K Units

- **Time Slice**
  - = 9.0 Units

8 Rings of 2 Topology
Heart – Based Communication Strategy Using MultiRing

- Time Slice = 9.0 Units
- Average Communication Load = 900K Units
Heart – Based Communication Strategy Using MultiRing

- Time Slice = 9.0 Units
- Average Communication Load = 200K Units
Heart – Based Communication Strategy Using MultiRing

- **Communication Load** is now Quite **Low**. Therefore, The **Time Slice** can now be **Reduced** Considerably.
Heart – Based Communication Strategy Using MultiRing

- Time Slice = 4.5 Units
- Average Communication Load = 300K Units
Heart – Based Communication Strategy Using MultiRing

8 Rings of 2 Topology

- Average Communication Load = 400K Units
- Time Slice = 4.5 Units
THANK YOU