Towards a Taxonomy of Performance Metrics

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Overview of the Paper

- Discusses deficiency of rigorous taxonomy for performance metrics in Computer Science.
- Defines taxonomy or rather 'rigorous' taxonomies.
- Importance of recursion in developing rigorous or non-overlapping taxonomies.

- Dimensional Analysis

- Correlation of metrics in physics with performance metrics.

- Some innovative metrics

- In summary: Exploration into the conceptual space of Performance
Deficiency of metrics for Performance

- Several architectural taxonomies exist.
- Serious deficiency of taxonomies to evaluate performance of computers - Due to lack of accepted taxonomies in the community.
- Leads to controversies in relative performance evaluations.

Proposal by Worlton

- Concept of taxonomy
- Nature of taxonomies - How should a taxonomy not be?
- An truly interesting taxonomy of performance metrics
Taxonomies

- One way of keeping track of complexity: Classification
- Taxonomies have to be rigorous.
  - Rigor:
    - Must be exhaustive and exclusive- Must list all characteristics of category and be non-overlapping.
    - Should help delineate the boundaries of a discipline.

Example of a *mild* taxonomy

<table>
<thead>
<tr>
<th>Measurable Components</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>Characteristics of an application—number of floating-point operations or logical operations, amount of memory traffic, total storage requirements, and branch behavior.</td>
</tr>
<tr>
<td>V</td>
<td>Degree of vectorization, average vector lengths, and strides.</td>
</tr>
<tr>
<td>P</td>
<td>Degree and type of parallelism, granularity.</td>
</tr>
<tr>
<td>M</td>
<td>Memory references, number relative to floating-point operations, access patterns, likelihood of occurring in various levels of a hierarchical memory system.</td>
</tr>
<tr>
<td>I/O</td>
<td>Storage requirements (if they exceed the capacity of an extended or virtual memory).</td>
</tr>
</tbody>
</table>

Fig. 1. Classification of the measurable components of an application.
Fig. 3. Classification of multiprocessor interconnection networks.
But what of resources that can't be manipulated?

- Such as space and time

And emerging *methods of manipulation*?

- **Such as Interfaces (HCI)**
Templates

- Graphical templates show the relationships between categories.
- A taxonomy is usually a taxonomy of taxonomies in the dimensions displayed.
  - 0-D taxonomy: Single metric
  - 1-D taxonomy: List
  - 2-D taxonomy: Tree
- Problem with templates - Lack of representation of synthesis of categories.
- Cladograms: Show an evolutionary relationship.
- Matrices: Tree that exhibits the same characteristics at some level of branching.
- Compound Matrices: When a category of a matrix is subdivided into other categories, a compound matrix representation is easier.
Illustrations

Fig. 5. A cladogram for the evolution of program control.

<table>
<thead>
<tr>
<th></th>
<th>SHARED MEMORY</th>
<th>DISTRIBUTED MEMORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMD</td>
<td>1 2</td>
<td>3 4</td>
</tr>
<tr>
<td></td>
<td>5 6</td>
<td>7 8</td>
</tr>
<tr>
<td>MIMD</td>
<td>9 10</td>
<td>11 12</td>
</tr>
<tr>
<td></td>
<td>13 14</td>
<td>15 16</td>
</tr>
</tbody>
</table>

Fig. 8. A compound matrix for selected architectural attributes.
Recursion in taxonomies

- When classifications become very complex and standard templates become insufficient, *recursion is used* to represent relationships.
- Resort to recursion when a category holds a multi-dimensional template.

![Hyper-dimensional template of computer architectures](image)
Some templates: A 24-way template of Performance Metrics

A rigorous taxonomy of performance metrics should include
- *Fundamental* and *Derived* units
- Modes of manipulation or *functions*
Fundamental Metrics

- Occam's Razor:
  - Do NOT multiply categories needlessly.

- Returning to the fundamentals
  - Are fundamental units of performance analogous to the fundamental units in physics?
  - Length:
    - In analyzing algorithms, *Length of processing* is determined by *Time Complexity*
    - *Space complexity* refers to amount of storage - Also a length metric.
  - Mass:
    - Idea of *mass* of a program - Number of floating points operations/second within one instruction count.
Innovative Metrics

- New metrics required to measure new capabilities.
- Scaling metrics:
  - Hold system size constant and increase problem size.
  - Grand Challenge problems - Time intractable
  - Proportionate scaling

Fig. 17. A scaling surface for parallel computation.
A serial fraction metric

Karp-Flatt metric:

\[ f = \frac{\frac{1}{s} - \frac{1}{p}}{1 - \frac{1}{p}} = \frac{p/s - 1}{p - 1}, \]

An incremental efficiency metric - Performance of a parallel computer when the number of processors increases.

\[ e_n = E_n / E_{n-1} \]
Conclusion

- This paper explores the conceptual space of performance metrics.

- Reports the lack of rigorous taxonomy as a serious deficiency.

- Reiterates that rigorous taxonomies are necessary for the development of any science.

- Proposes some very interesting taxonomies for performance metrics.
THANK YOU !