Towards a Taxonomy of Performance Metrics

Jack Worlton

Presentation by
Supraja J

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

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

Fig. 1. Classification of the measurable components of an application.

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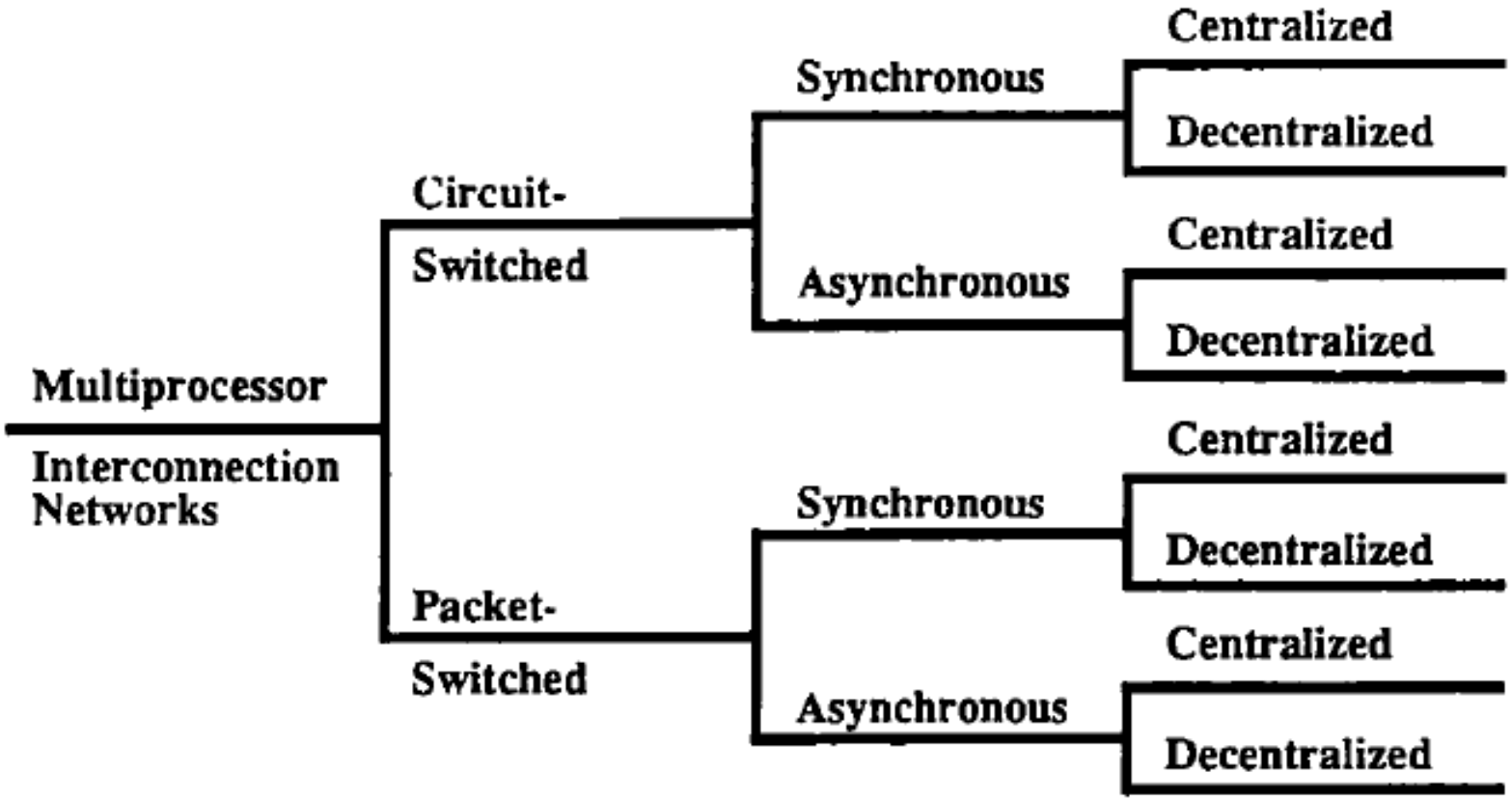

Fig. 3. Classification of multiprocessor interconnection networks.

(Continued) Example of a rigorous taxonomy

	Methods of Manipulation		
Resources	Processing	Storage	Communication
Matter	*Blast furnaces*	*Warehouses*	*Railroads*
Energy	*Power stations*	*Batteries*	*Power grids*
Information	*CPUs*	*Memories*	*Networks*

Fig. 2. The van Wyk taxonomy of technologies.

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 sub-divided into other categories, a compound matrix representation is easier.

Illustrations

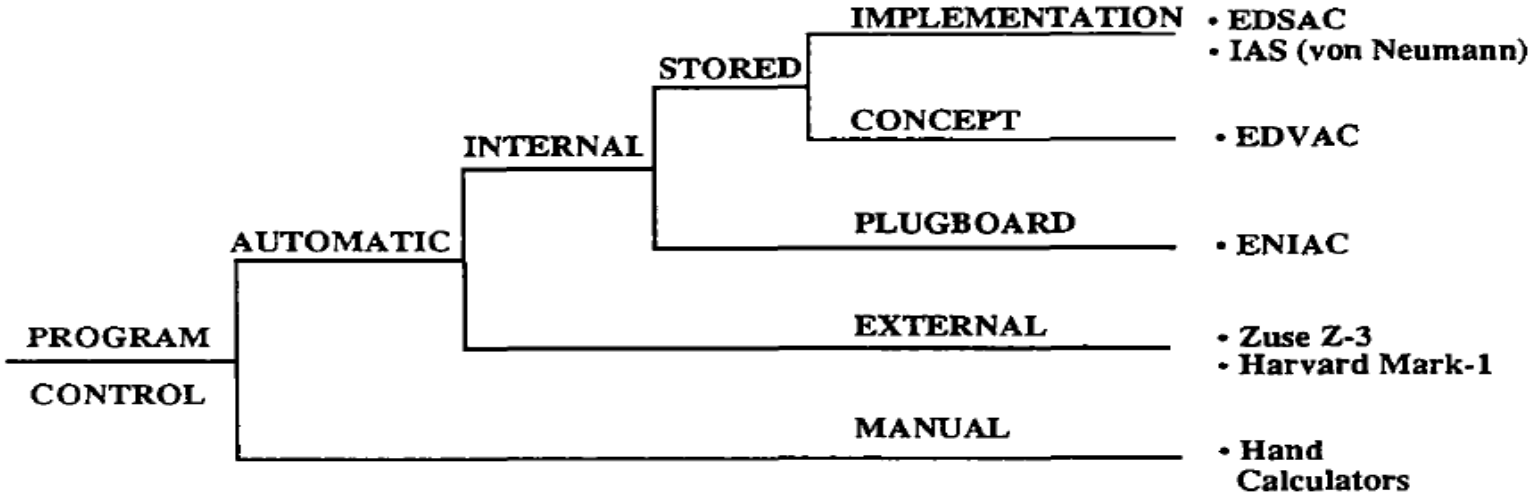

Fig. 5. A cladogram for the evolution of program control.

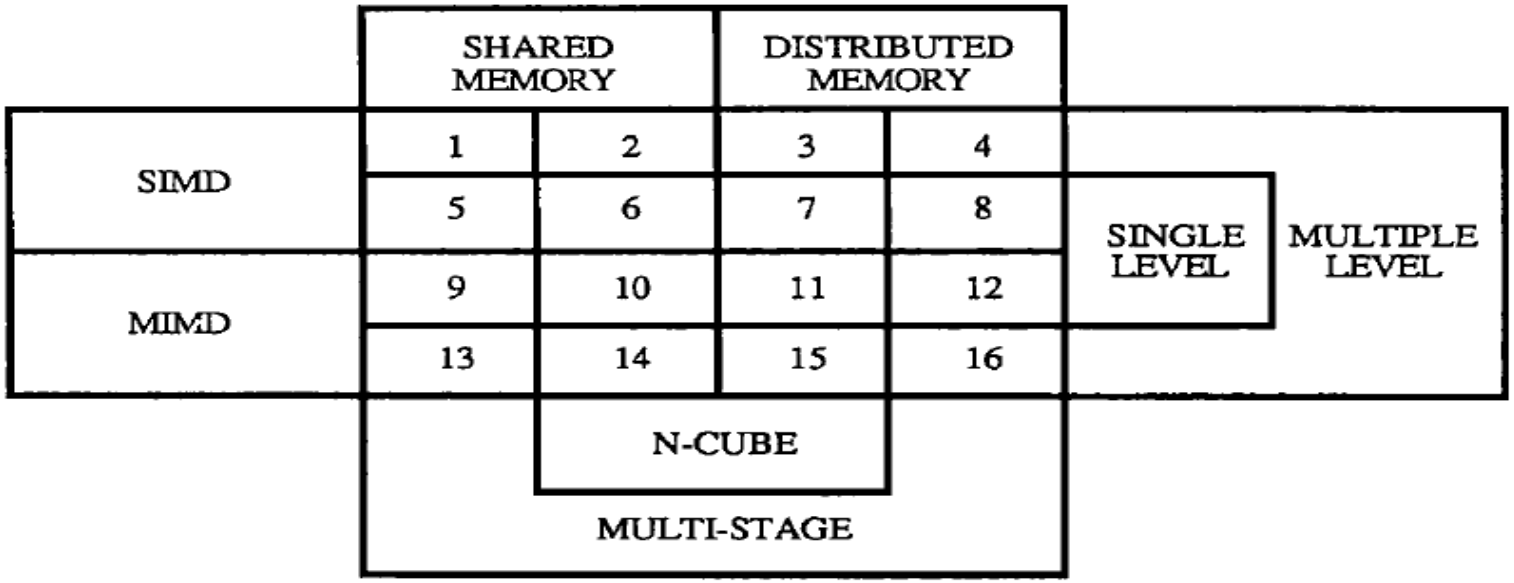

Fig. 8. A compound matrix for selected architectural attributes.

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.

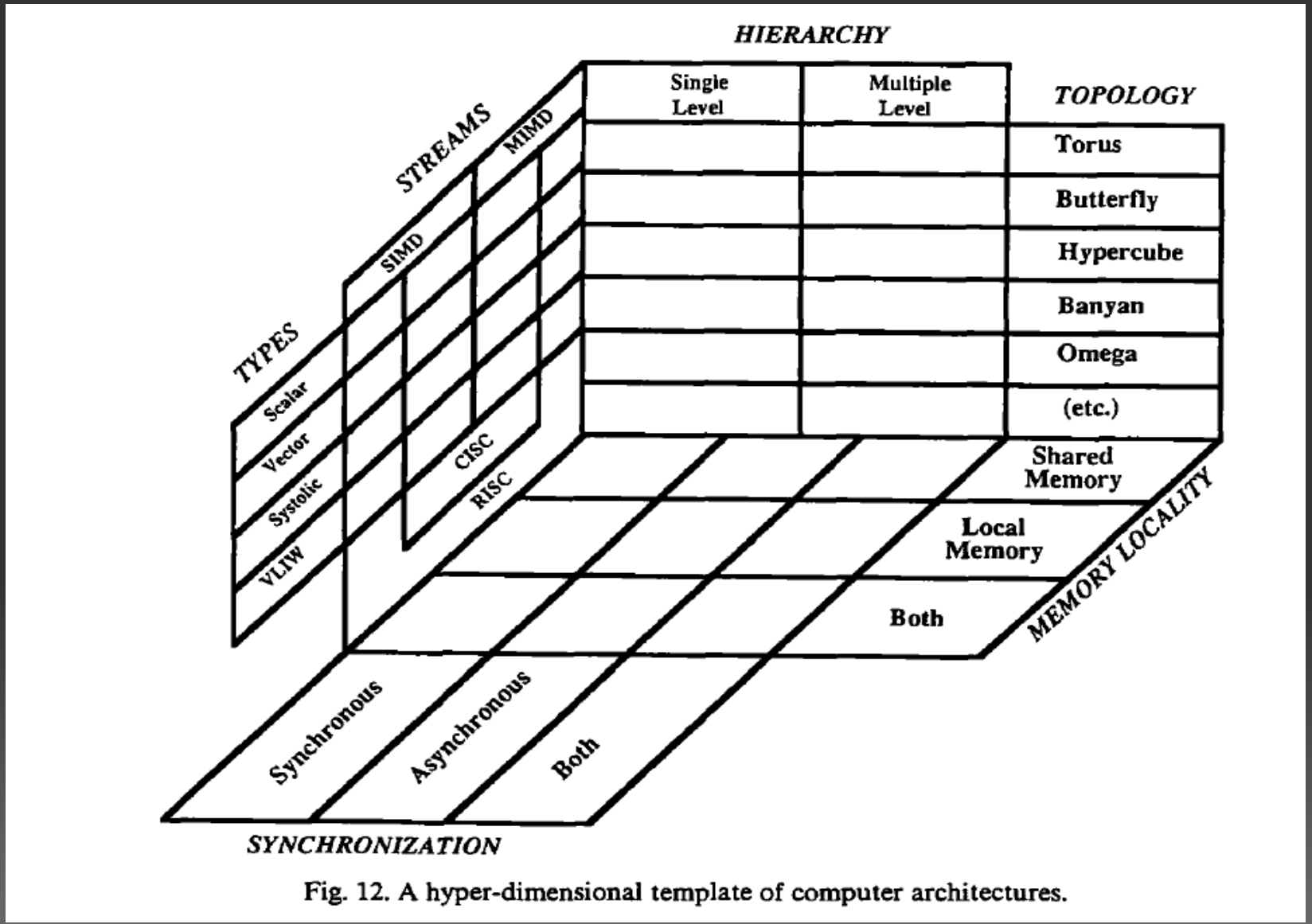

Fig. 12. A hyper-dimensional template of computer architectures.

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*

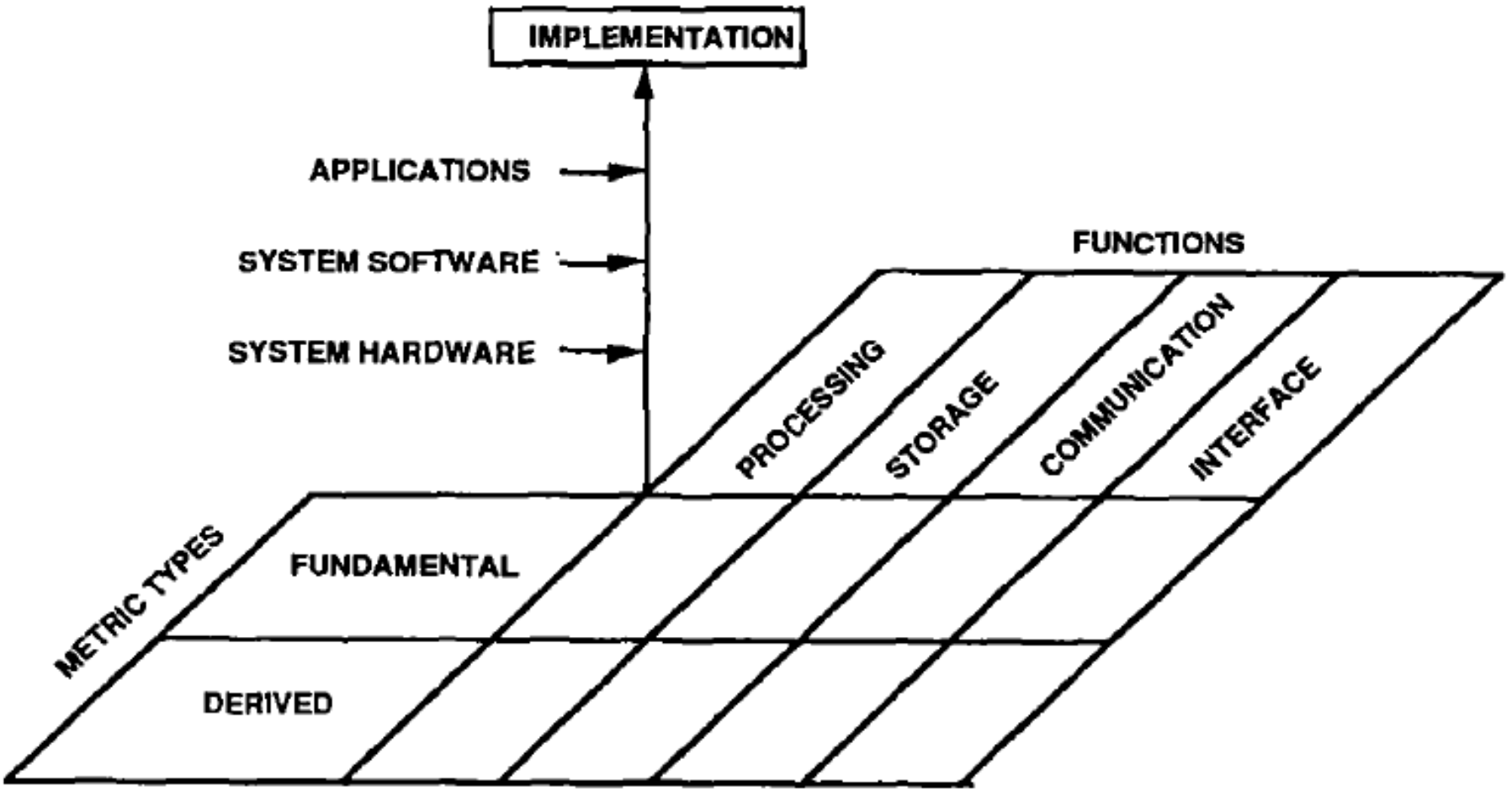

Fig. 15. A 24-way template for performance metrics.

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

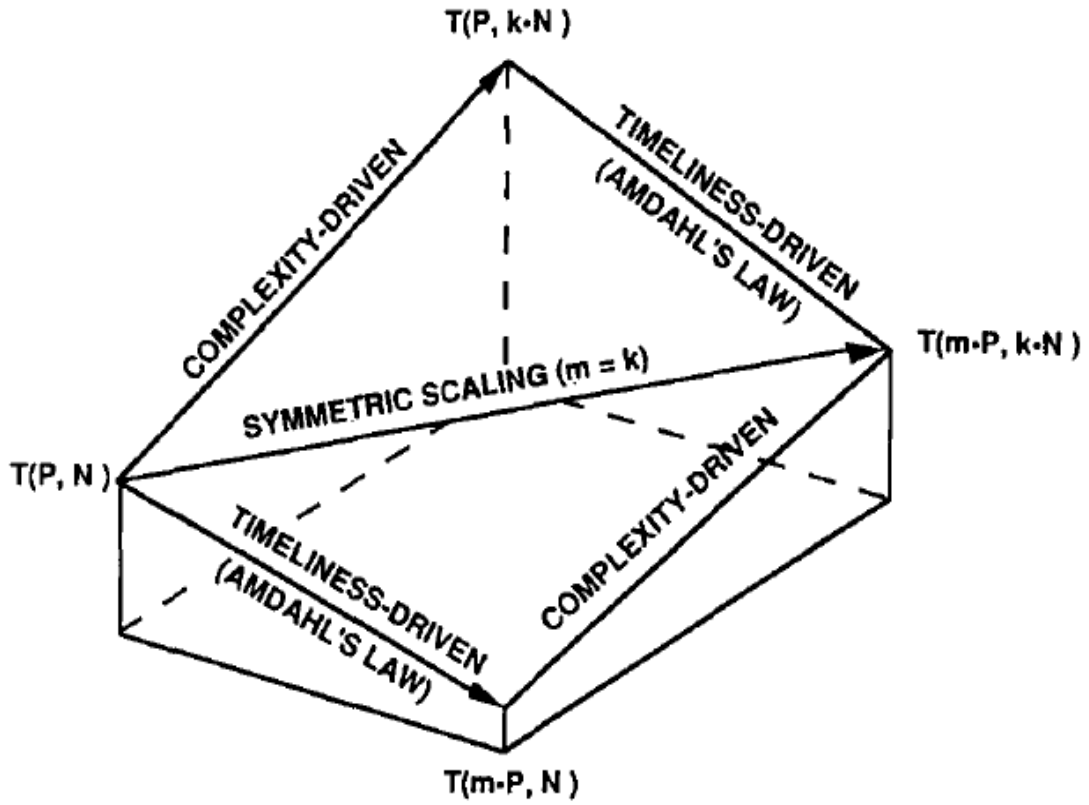

Fig. 17. A scaling surface for parallel computation.

A serial fraction metric

Karp-Flatt metric:

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

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 !