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**Decision Analysis, Distributed Forces
and Complex Causality**

Jeffrey R. Cares

73rd MORSS

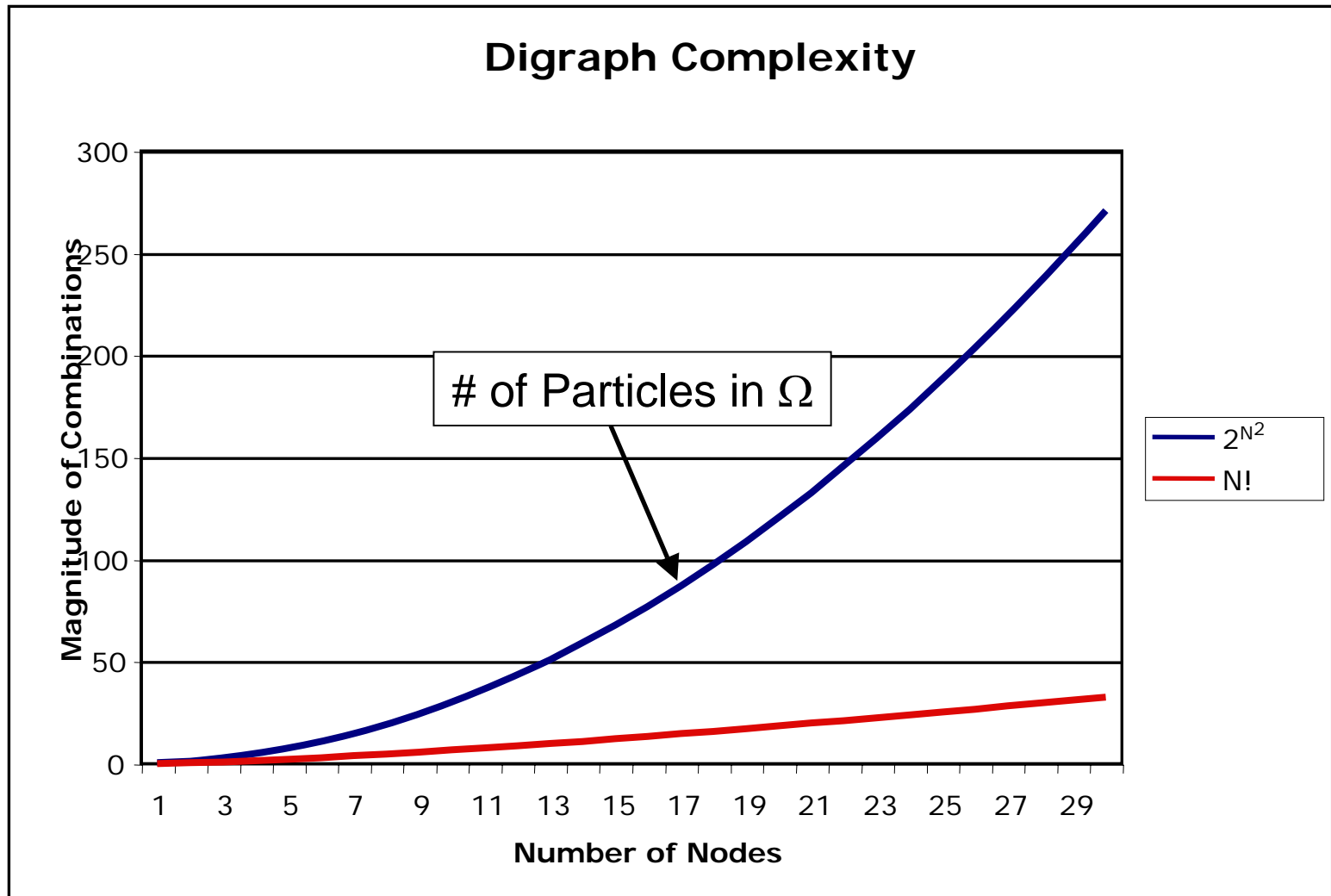


Introduction

- Distributed, networked systems are “complex systems”
- Complex Causality and distributed, networked systems
 - Even if desired effects (e.g., performance goals) are provided, methods to achieve them may be elusive
 - Control will be questionable
- Complex Causality and NCW/IAW MOEs
 - We cannot be sure that our measures actually measure effectiveness, because we cannot trace improvements in inputs to improvements in outcomes.

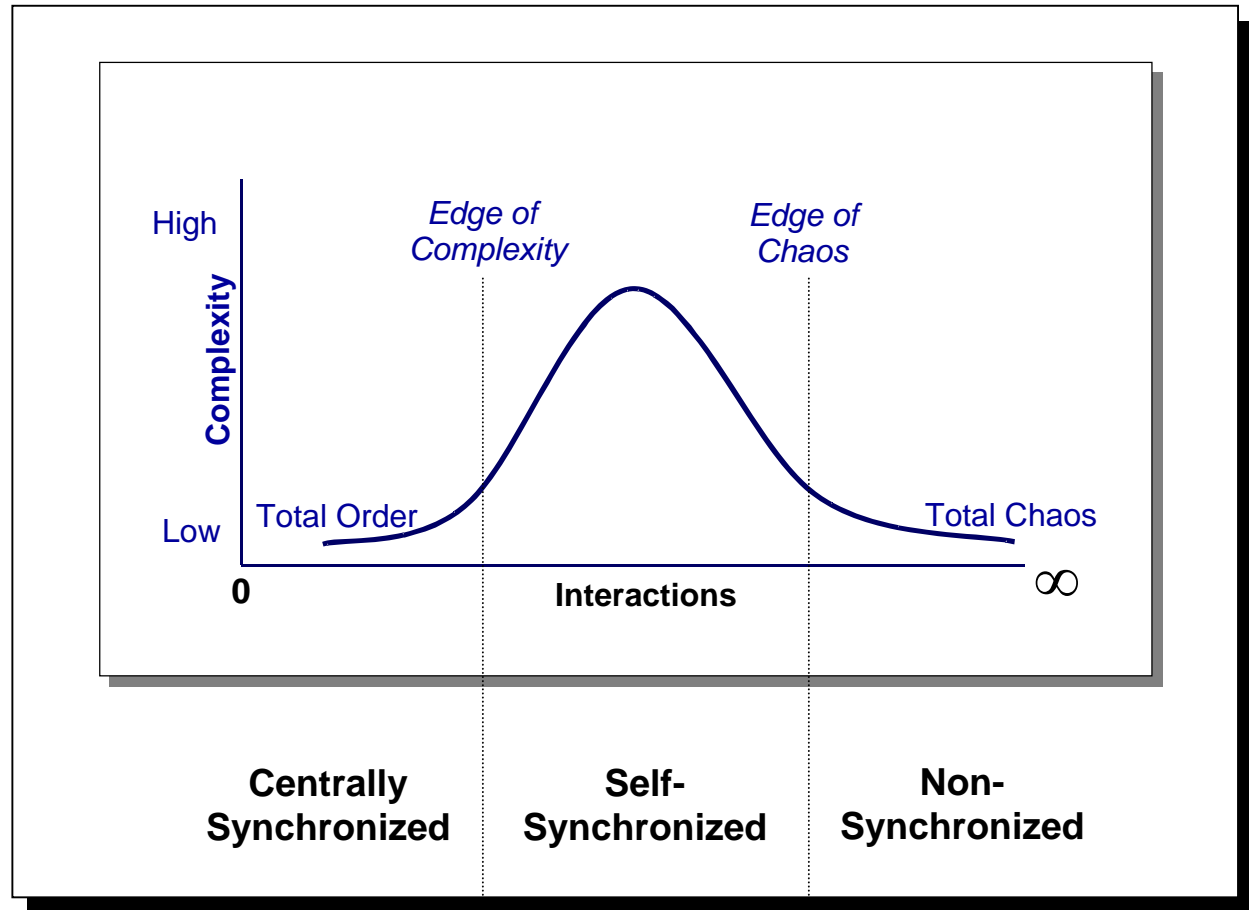
Combat Model Potential Complexity

Complex
Causality



Synchronization Continuum

Complex
Causality



Each extreme is rare; most real cases are likely in the middle (that is, partly centrally synchronized and partly non-synchronized)

“Simple” Causality

Complex Causality

- Hume (1748)
 - A notion fundamental to human cognition
 - Basic idea, necessary and sufficient conditions
- Russell (1913)
 - Functional relationships among state variables of a system
- Suppes (1970)
 - “Probabilistic Causality”: reaction to Quantum Mechanics
 - Causes raise the probability of their effects
- Mackie (1974)
 - INUS Conditions: Insufficient but non-redundant part of an unnecessary but sufficient condition
 - e.g., A lit match can cause a forest fire but not all lit matches cause forest fires

Causality is well-defined for deterministic and stochastic linear and chaotic systems



Simple Deterministic Causality

Requires “regularity” and *ceteris paribus* (among other constraints)

Complex
Causality

$$y = m \cdot x + b$$

$$m = 1, b = 1$$

$$\text{If } x = 1, y = 2$$

$$\text{If } x = 2, y = 3$$

$$\text{If } x = 3, y = 4$$

$$\text{If } x = 4, y = 5$$

.....

- **Regularity:** The operators =, •, and + have consistent meaning and the result behaves in a “regular” way
- ***Ceteris Paribus:*** Fixing all other variables results in a cause always being followed by the same effect
- **Separability:** b can be ignored in a description of the behavior



Simple Probabilistic Causality

Requires “regularity” and *ceteris paribus* (among other constraints)

Complex Causality

A causes B iff:

$P(B | A) > P(B | \text{not-A})$

- Regularity, *Ceteris Paribus*, Separability still pertain

- Asymmetry and spurious correlations are issues

- Biggest problem: *Reductive analysis* is not possible. In fact, there is no theory that details the systemic connections between causation and probability



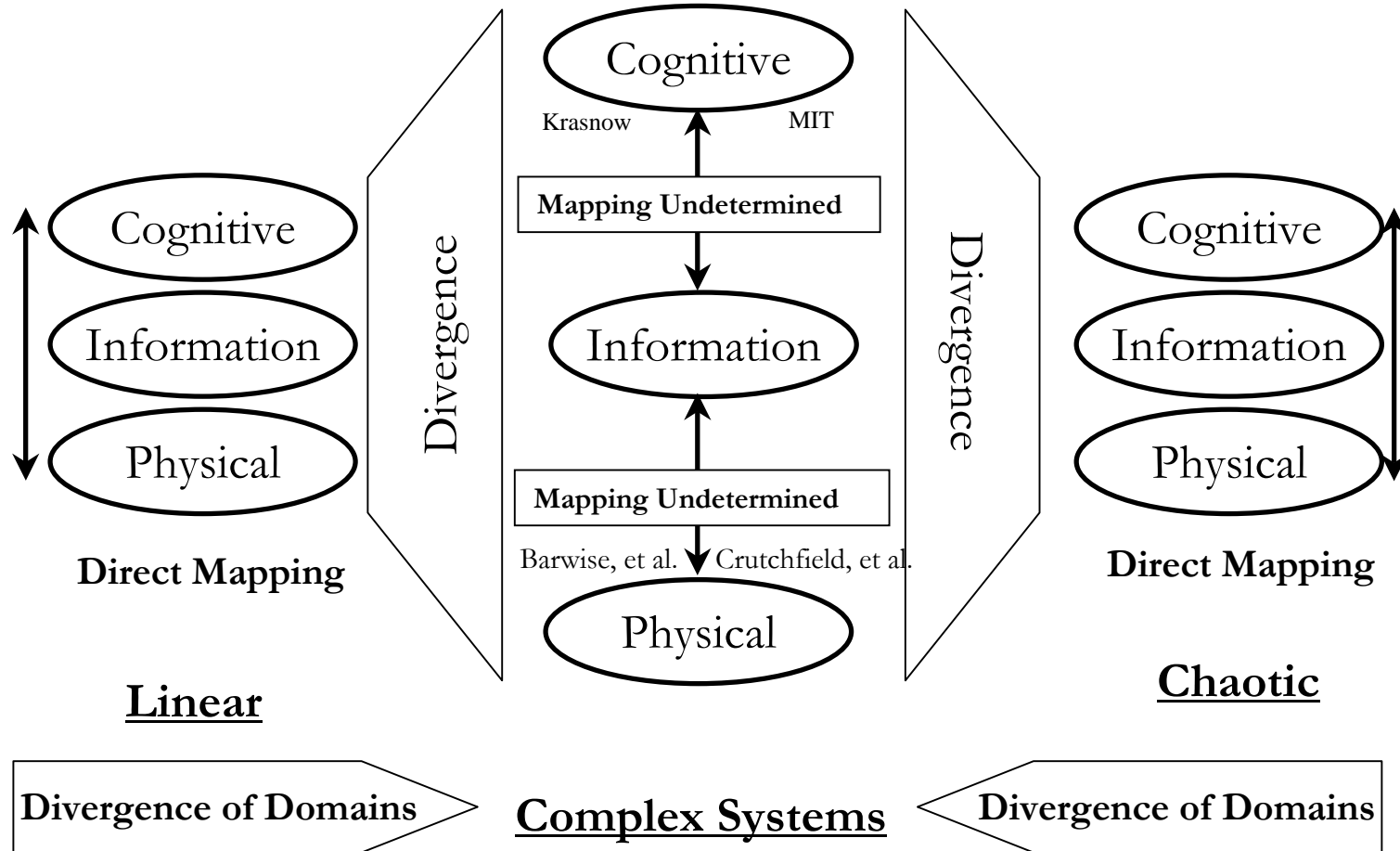
Complex Causality

- Wagner (1997)
 - The notion of regularity does not hold for non-linear, complex systems
 - The effect depends on the context
- Hohler and Gumerman (2000)
 - New notion of causal regularity
 - Regularity exists because of the behavioral and cognitive linkages between context and action at the level of the agents
 - “Dual Status” of variables as outcomes of behavior and as contexts for behavior
- Barwise, Seligman (1997)
 - Information flow is a result of regularities in distributed systems
- Pearl, et al (1998+)
 - Structural Equation Models and complex causes
- Crutchfield and Shalizi (1999+)
 - Computational Mechanics: initial results in prediction, pattern discovery, causality in complex systems

Complex Causality

A Research Frontier

Complex
Causality





Conclusions

- There are no tools for determining complex causality
- Brute Force approaches exist
- Fundamental research has recently started (including genomics research)
- New visions of NCW, EBO and IAW are built on a base of sand
 - Hopefully, this condition is temporary



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Complex Systems Research

Process Innovation & Analysis

Strategic Investment Advice

Future Concept Generation

Corporate/Government War Games & Events

Questions?