

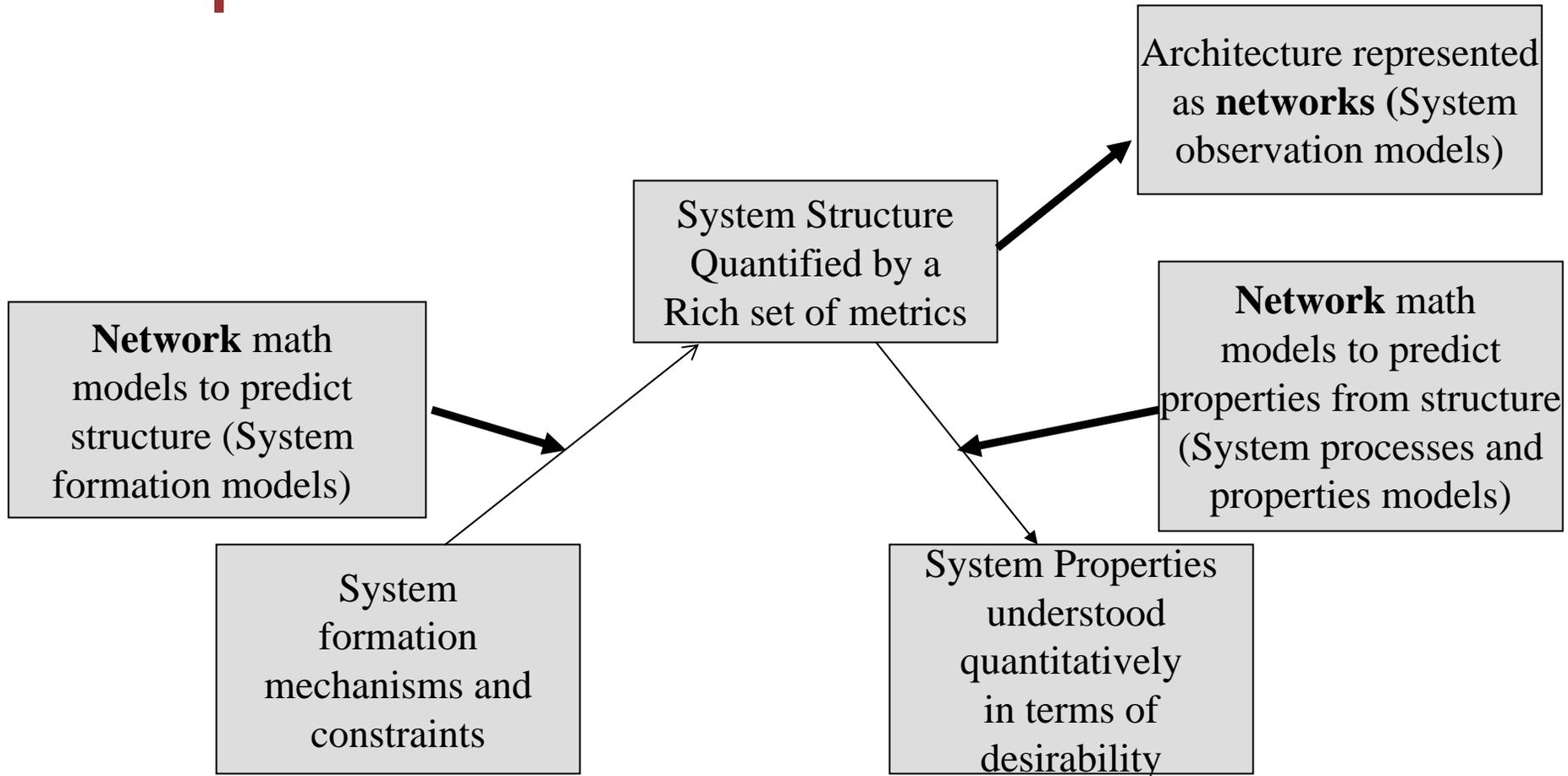
Network Analysis and deeper understanding of complex systems: Positives

- Some helpful general insights: For example “**Small Worlds** are Ubiquitous” in large (lots of nodes or links) systems
- Network Analysis is a methodology that nicely crosses over between technical concerns (much sociology work) and technical matters (OR and other extensive network approaches). This crossover or dualism is at the root of Engineering Systems issues as we need to develop quantitative methods which treat both aspects.
- Comparative studies of structures in very different systems and the development of “observation” techniques to arrive at some potentially important structural information from a network model.
 - Community analysis
 - Motif analysis
 - Centrality and other social structure metrics
- Some superb models have been developed for search, navigation, organization design and distribution systems. A characteristic of these exemplar modeling efforts has been that they all combine previously separate sociology, and OR/CS approaches.

Network Analysis and deeper understanding of complex systems II: Negatives

- Overgeneralization (as happened 50 years ago in “General Systems Theory”). The clearest example was (is?) the tendency to assume that power laws of degree distribution imply “Scale-Free” Structures because one model that is consistent with power laws leads to such structures. However, it is clear now (and known much earlier) that multiple models lead to power laws. It is also now clearer that power laws are “More Normal than Normal” distributions when variation is not bound.
- The + r, - r story for sociological vs technological systems also appears to be premature generalization but this has not resulted in the “cottage industry” that power laws did nor the mental block that “scale-free” has raised.
- Not nearly enough attention to data quality and facts: “it isn’t what you don’t know that gets you in trouble but what you think you know that just ain’t so that does.”
- Methods for handling really large datasets are needed
- Not enough attention to realistic “System Formation Models”

Schematic of Engineering System Model Purposes



Network Model types of interest (from lecture 12)

- **Models/algorithms used to “observe” systems**
 - Calculation of structural metrics
 - Communities, motifs, coarse-graining, hierarchy
- **Models for predicting/explaining Structure**
 - Models for formation/growth processes of systems
 - Most network models such as random, small-world etc. implicitly fall in this category
 - Cumulative advantage, preferential attachment, bipartite community formation, heuristic optimization relative to constraints, hierarchy (or heuristics) + random
- **Models for predicting/explaining properties of systems**
 - Predicting properties from structure – architecture
 - Flexibility, robustness, performance of functions
 - Operational processes or functions
 - Communication, problem solving, decision-making, learning
 - Search and navigation
 - Failures and cascades, epidemics

Lecture 6,7, 8 and 18

Sociology

Lectures
7,10,12, 14,
15, 18 and 20

Sociology,
Engineering
CS & OR

Lectures
12, 14, 17,
18 and 20

OR



Network Analysis and deeper understanding of complex systems III: A possible future approach

- Utilization of the framework espoused here should help keep the areas of ignorance and the need for models of use in design more clearly in focus.
- Why should we care?
- How much progress have we made in complex system design (for example organizational design) from 1940-2000?

Comparative Progress in Understanding and performance: CLM objective/subjective observations

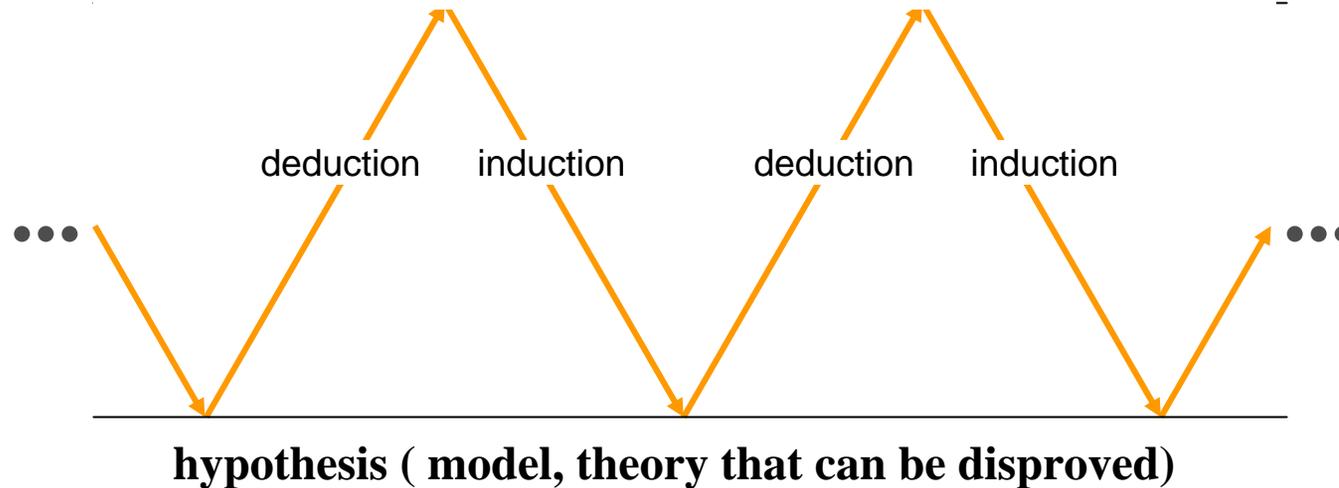
- 1940-2000 improvement
 - Small-scale electro-mechanical systems (x40-100)
 - Energy transformation systems (x 10-20)
 - Information processing systems (x 10^{12} to 10^{15})
 - Cosmology (x 30-100)
 - Paleontology (x 50)
 - Organizational theory and practice (x *1.1 to 2*)
 - Economic systems (x *1.1 to 2*)
 - Complex large-scale socio-technological systems (?)

Network Analysis and deeper understanding of complex systems II

- Why should we care?
- How much progress have we made in complex system design (for example organizational design) from 1940-2000?
- • What is needed to greatly improve the *practice* of complex social/ technological system design?
- The major opportunity is to transition from the “pre-engineering” (experiential or craft) approach now widely used to a solid (post 1870 at least) engineering approach to these design problems. This basically involves moving our learning in these areas so that a “Cumulative” Science evolves (rather than “paradigm of the month science). *What does this entail?*

The Iterative Learning Process

Objectively obtained quantitative data (facts, phenomena)



As this process matures,
what new can the models accomplish?

The major accomplishment will be the rapid facilitation
of a transition to engineering (vs. craft approaches) for the
design of complex social/ technological systems

Comparative Progress in Understanding and performance: CLM objective/subjective observations

- 1940-2000 improvement
 - Small-scale electro-mechanical systems (x40-100)
 - Energy transformation systems (x 10-20)
 - Information processing systems (x 10^5 to 10^7)
 - Cosmology (x 30-100)
 - Paleontology (x 50)
 - Organizational theory and practice (x *1.1 to 2*)
 - Economic systems (x *1.1 to 2*)
 - Complex large-scale socio-technological systems (?)
- • Possible reasons for limitations in progress to cumulative science
 - Lack of attention by deep thinkers
 - Low utilization of mathematical tools
 - “Hardness” of problem particularly *human intent*
 - *Difficulties with detailed quantitative observation to improve models (hiding of data, privacy etc.)*

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- The major opportunity is to transition from the “pre-engineering” (experiential or craft) approach now widely used to a solid (post 1870 at least) engineering approach to these design problems. This basically involves moving our learning in these areas so that a “Cumulative” Science evolves (rather than “paradigm of the month science). *What does this entail?*
- • The critical need is to greatly accelerate the rate of improvement in practice is *objective methods for quantitative observation* to accelerate the development of “observation-hardened” and well-understood “simple” models.