Probabilistic Methods for Modeling Interdependent Complex Systems

Iris Tien, Ph.D.

Assistant Professor

School of Civil and Environmental Engineering

Georgia Institute of Technology

Food Energy Water Nexus Workshop | NSF and AIChE

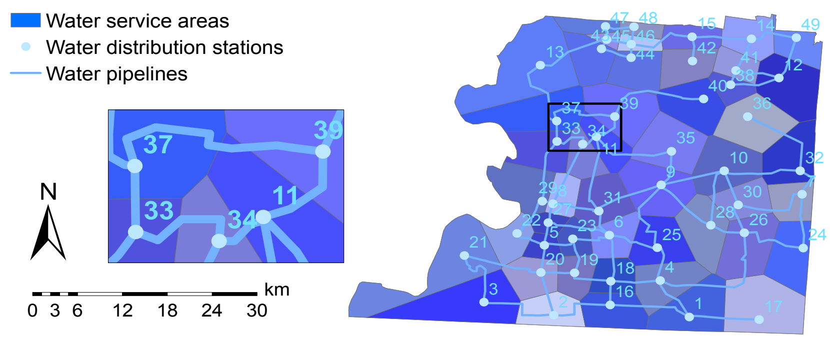
Panel 3: Systems Approaches

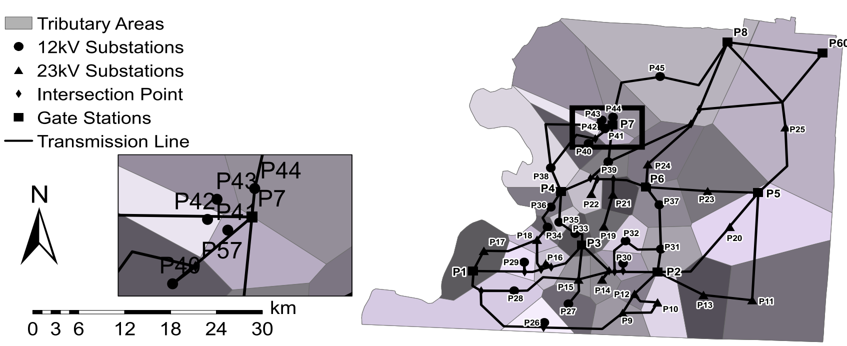
October 8, 2015

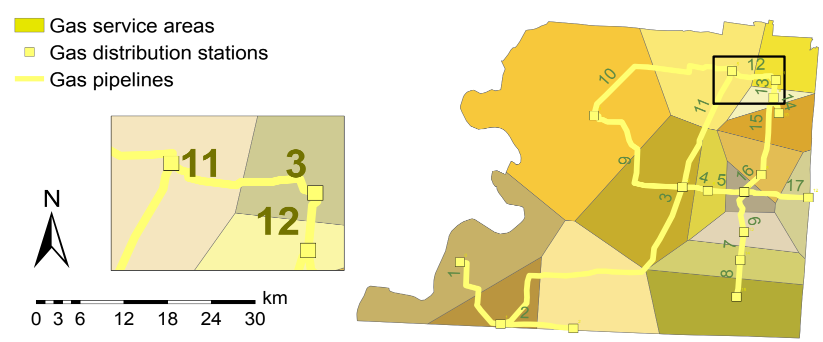
Systems modeling

- Complex systems, comprised of many interconnected components
- Interdependencies between systems

e.g., water, power, and gas infrastructures



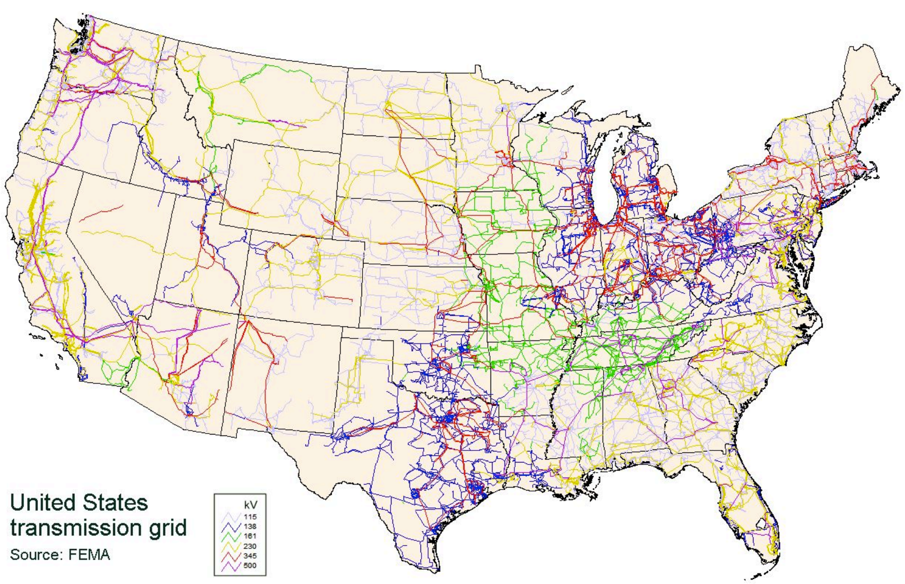




From: Gonzalez et al, "The interdependent network design problem for optimal infrastructure system restoration," *in review*

Systems modeling

- Support decision making in system design, management, and rehabilitation
- Achieve efficient resources management and improved system performance (reliability, resilience)

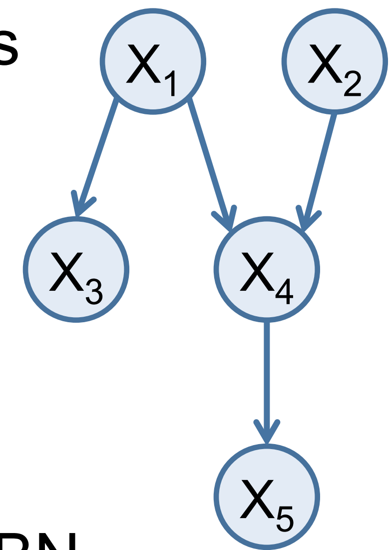


- Challenges
  - Uncertain information
  - Evolving information
  - Large, complex systems

One method: Bayesian networks (BNs)

- DAG: nodes represent RVs, links dependencies between variables

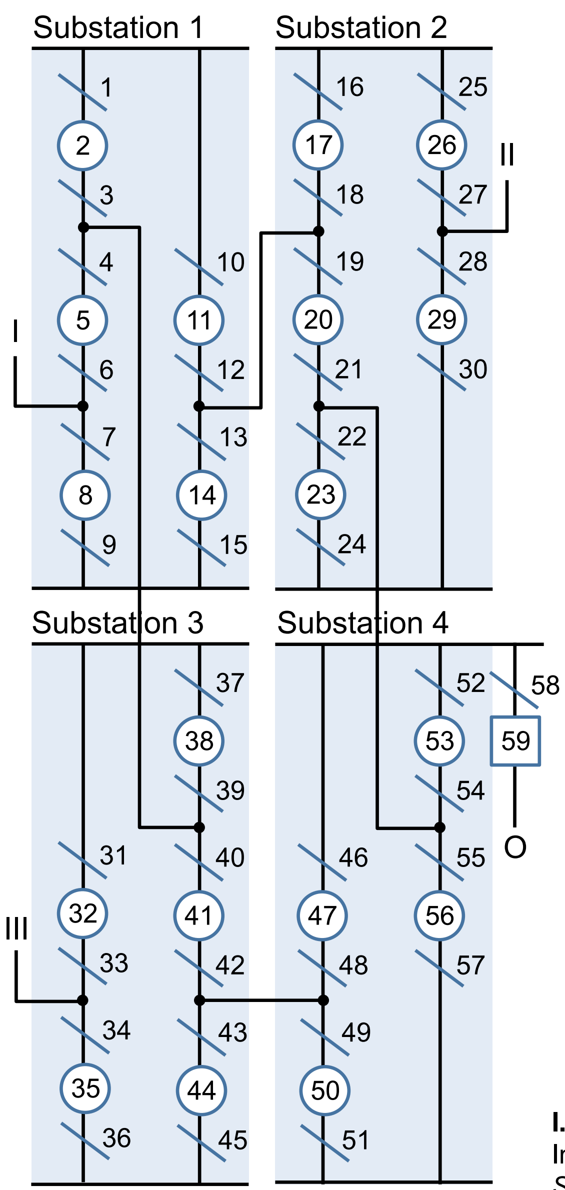
$$p(\boldsymbol{x}) = \prod_{i=1}^{n} p(x_i \mid Pa(x_i))$$

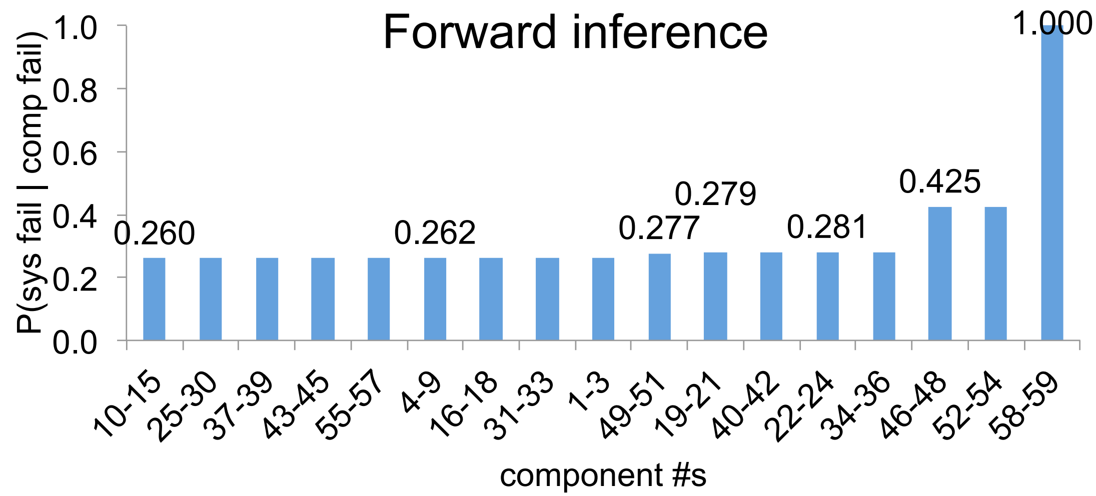


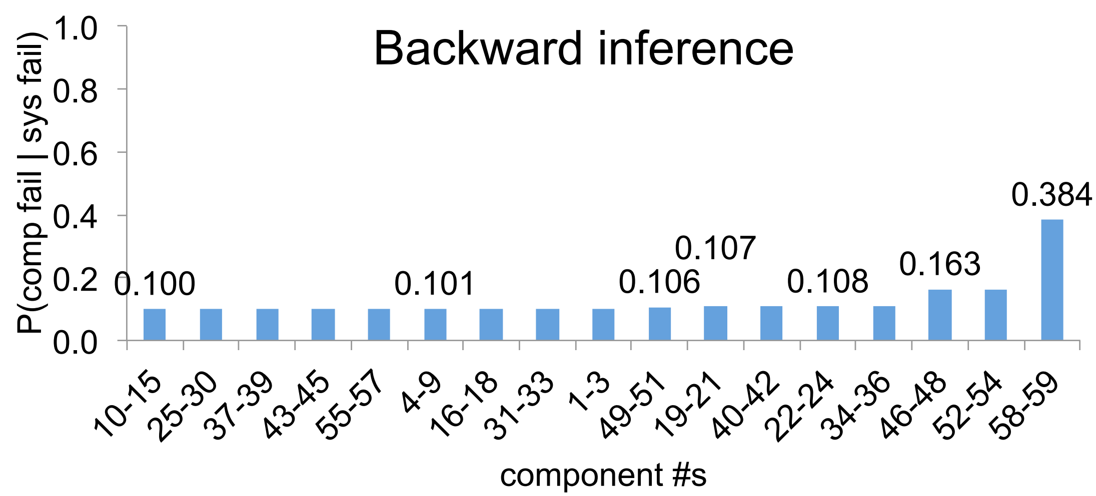
- Advantages
  - *Uncertain information*: probabilistic model to support decision making under uncertainty
  - *Evolving information*: evidence entered into BN propagates through the network, allows for updating as new information becomes available
- Traditionally limited by the size and complexity of system that can be tractably modeled as a BN → algorithms to enable larger systems to be modeled as BNs

Example

- Prior probabilities of failure for all components = 0.1



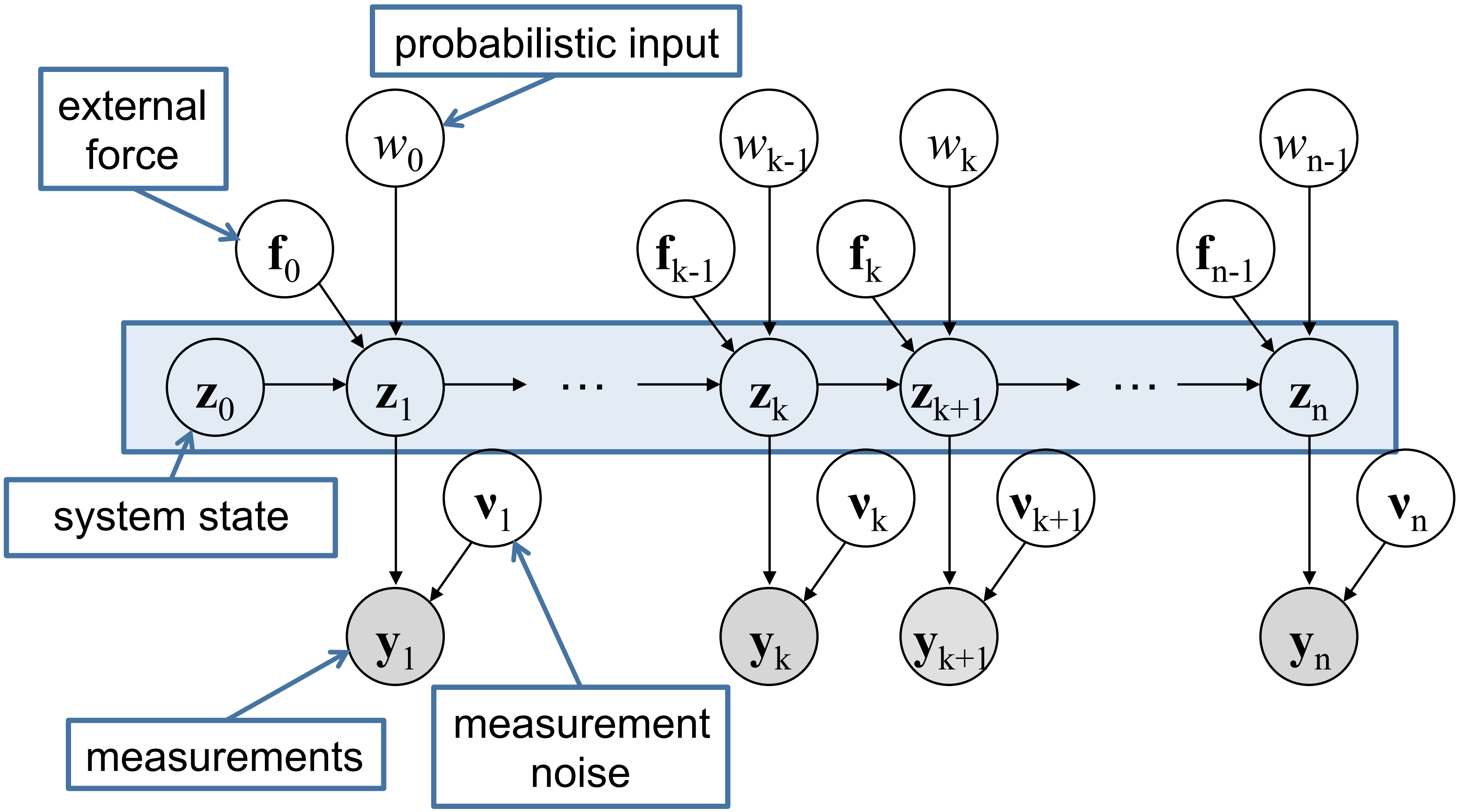




I. Tien and A. Der Kiureghian, "Algorithms for Bayesian Network Modeling and Reliability Assessment of Infrastructure Systems: Part II – Heuristic Augmentations to Improve Efficiency," *Reliability Engineering and System Safety*, *in review*

Modeling dynamic systems with data

- Graphical dynamic Bayesian network model



I. Tien, M. Pozzi, and A. Der Kiureghian, "Probabilistic Framework for Assessing Maximum Structural Response Based on Sensor Measurements," *Structural Safety*, *in review*

Conclusions for FEW Nexus

- Complex systems modeling
- Capturing interdependencies, tradeoffs among the three systems
- Collecting / validating / integrating data
- Metrics for system performance and sustainability

AIChE

contact: itien@ce.gatech.edu