# NME130 – Networked Systems

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# Uncertainty (title in the NME130 planning web page)

**Topics suggested in the first meeting:**

- Robustness and uncertainty (controls-ish)
- Bayesian theory, belief propagation
- Hypothesis testing (?), inference, decision making

# Assumptions and goals

(oriented toward the uncertainty part)

- **Assumptions at the beginning of the module:** Basic understanding of dynamical systems, optimization, stochastic processes, graph theory, …
  - Already have seen or experienced uncertainty (in other courses/modules)
  - Or are we teaching from scratch?
- **Goals:** understand
  - the types and effects of uncertainty
  - modeling uncertainty
  - familiarity with methods to handle
- Overlaps with almost all modules as well as new courses (optimization, data based modeling, stochastic systems).

# Module title: Uncertainty

We felt more comfortable with

- Robustness and uncertainty (controls-ish)

Seems very useful but we don't have a a good understanding of these (resort to expert opinion)

- Bayesian theory, belief propagation
- Hypothesis testing (?), inference, decision making

# Tentative topics – case studies

## Each already touches on uncertainty/robustness

- Robust control
- Robust optimization (worst-case and probabilistic)
- Game theory
- Sensitivity/perturbation
- Random networks/graphs
- Uncertainty in FSM (non-determinism)
- Synthesis theory (Bode, Shannon,…)
- …
- Estimation/system identification
- Bayesian theory, inference (?)
- Graphical models (?)

# What is the "uncertainty" submodule on?

- Pick a case study and discuss all aspects of it concerning uncertainty
  - Modeling, analysis, design in the presence of U
- Assume that case studies are already covered at multiple other places and try to unify (as much as possible)

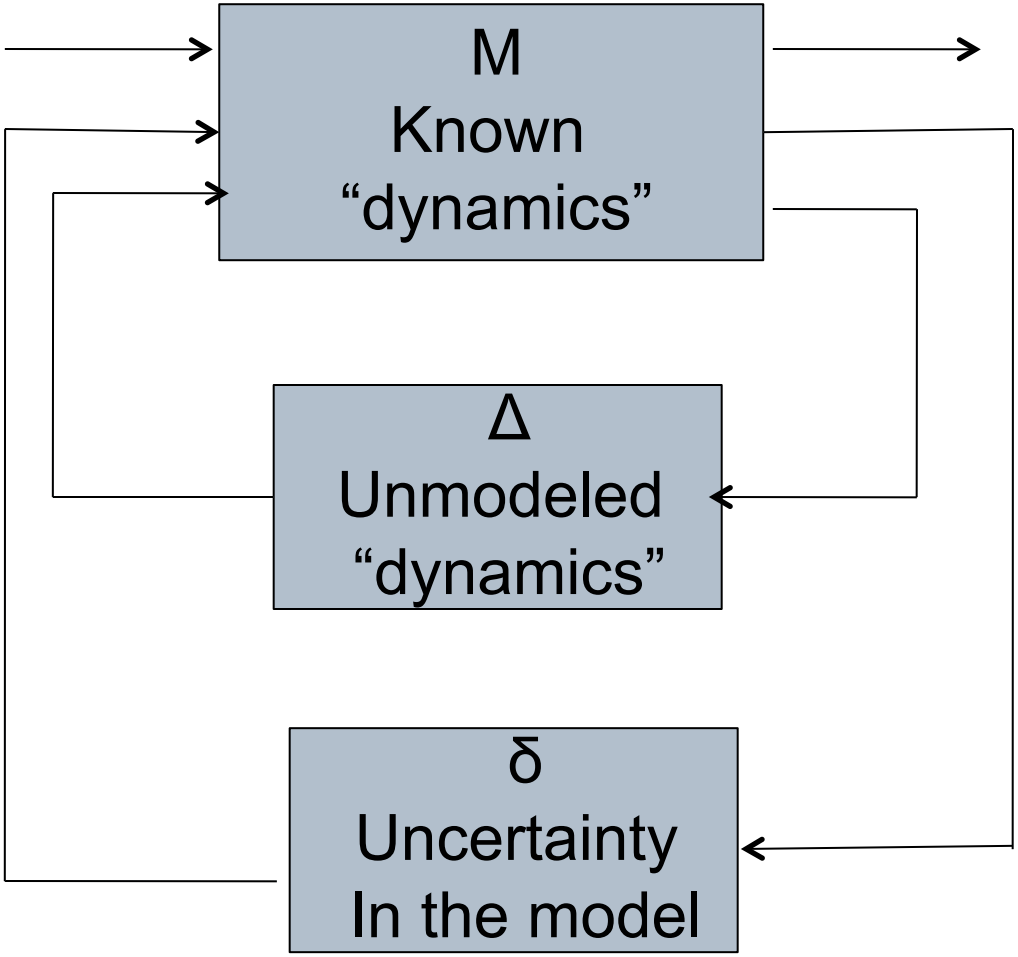
- We feel like the goal should be unification. Therefore, the module should be taught toward the end of the year.
  - Yet, we have case studies where we see effects of uncertainty that cannot be modeled in any existing single framework (see Alice)
  - Unification can be followed by an overarching case study (with bunch of open questions).

# Do we need …

- Unification of uncertainty descriptions in controls, computer science, networking, and optimization.
  - Is it possible?
  - To what extent?
  - Is it needed?

- There is no existing course focusing on uncertainty in such a wide range.
  - No useful textbook, popular book, etc.

# How much can we condense into a single framework?




Known dynamical system
LTL specs of the system
Nominal adjacency matrix

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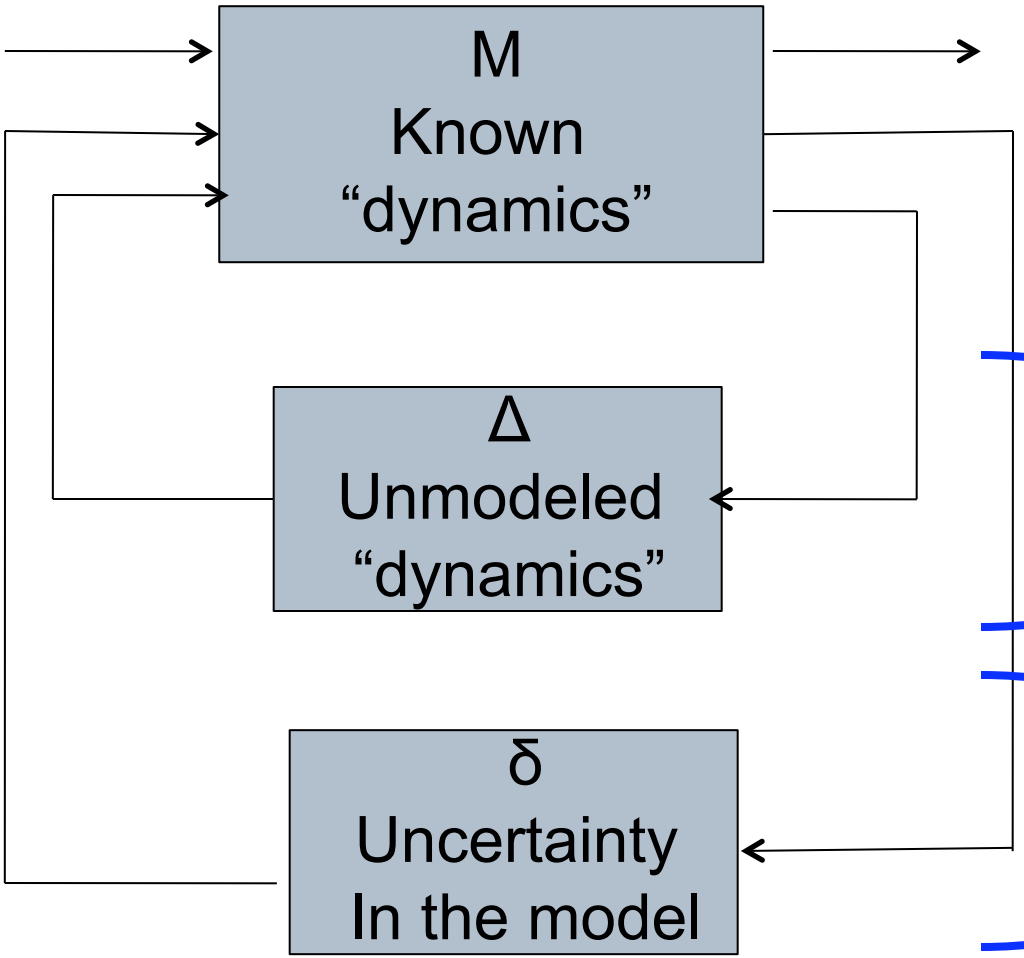


Known dynamical system
LTL specs of the system
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**Models of "what is known about what is not known"**

LTL specs for the environment/ adversaries, etc.
Norm bounds on unknown dynamics

Parameter uncertainties,
Perturbations in adjacency matrix

Is this a good way of unification?

# These seem useful…

- **Belief and Probability**
  Belief functions and probabilities, Events, partitions and Bayes' rule, Independence, Random variables, Joint distributions, Independent random variables, Exchangeability, etc.
- **Bayesian Network**
  Graphical Models, Inference in Bayesian networks, learning probabilities in Bayesian networks

WHERE DOES ALL THIS BELONG TO?

- a submodule on its own?
- is it part of ACM 116-216?

# A sample of topics from Michael Jordan's course at Berkeley (15 week x 3 hours)

- Sum-product algorithm, factor graphs
- Bayesian classification
- Exponential family
- The EM algorithm
- Conditional mixture models
- Hidden Markov models
- Markov properties of graphical models
- Junction tree algorithm
- Chains, trees, factorial models, coupled models, layered models
- Importance sampling
- Variational algorithms
- Dynamical graphical models
- Model choice: cross-validation, AIC, BIC and Bayes factors
- Decision networks, Markov decision processes and reinforcement learning

# Yaser Abu-Mostafa says…

His opinion on unification:

- Keep the focus on interesting case studies instead of unification
- Goal is to motivate for further reading(?) instead of unification

- Graphical models:
  - There is a full course on campus
  - He also teaches in 3-5 hours as a part of his learning course

# How to cover the material?

- Keep as two smaller modules
  - Graphical models (and all those other things we don't know about): can be taught almost anytime (after the basics)
  - Unification of uncertainty models: toward the end of the year (after covering different flavors in different modules)
- Uncertainty and Bayesian theory+ graphical models seem related. But, we don't quite see how.