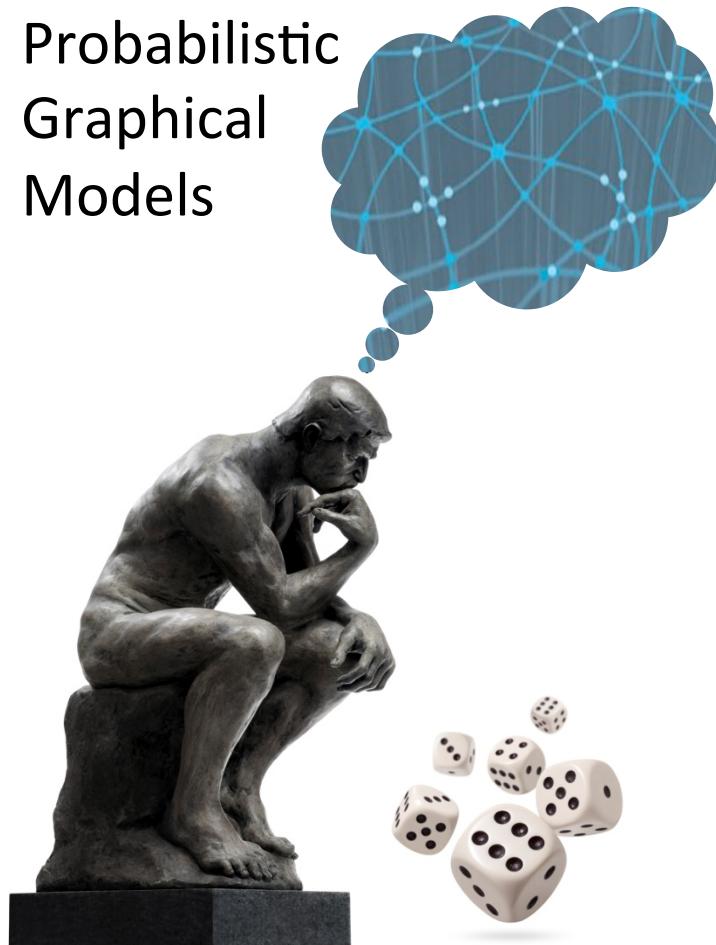


Probabilistic  
Graphical  
Models

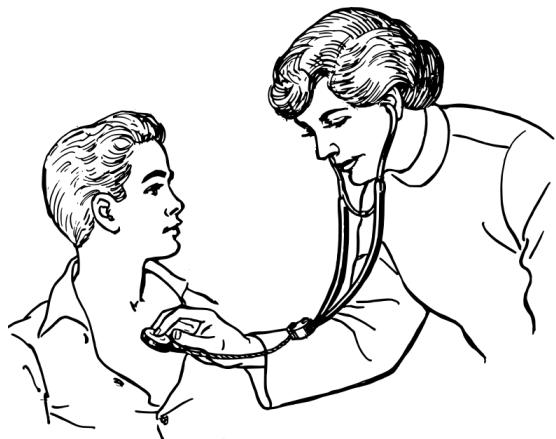


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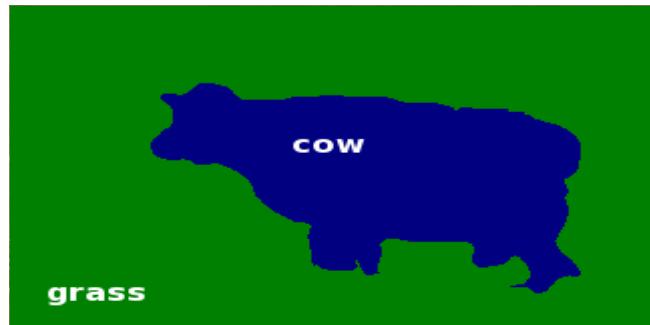
## Introduction

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# Motivation and Overview



predisposing factors  
symptoms  
test results  
diseases  
treatment outcomes

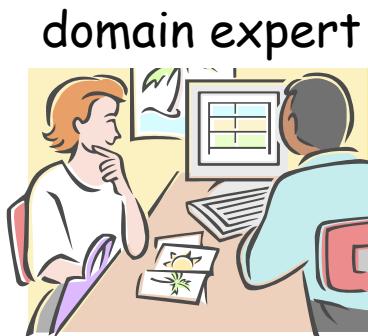


millions of pixels or  
thousands of superpixels

each needs to be labeled  
{grass, sky, water, cow, horse, ...}

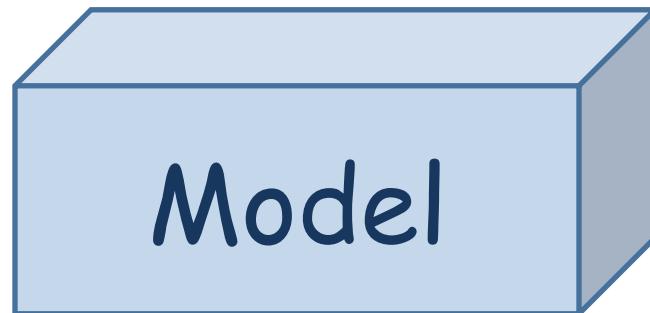
# Probabilistic Graphical Models

Daphne Koller

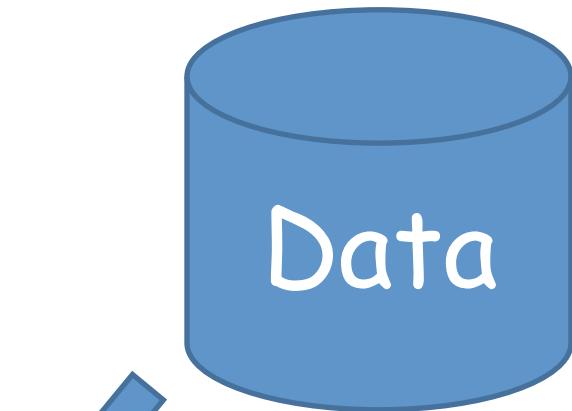


# Models

Declarative representation



elicitation



Learning

Algorithm

Algorithm

Algorithm

# Uncertainty

- Partial knowledge of state of the world
- Noisy observations
- Phenomena not covered by our model
- Inherent stochasticity

# Probability Theory

- Declarative representation with clear semantics
- Powerful reasoning patterns *conditioning  
decision making*
- Established learning methods

# Complex Systems

predisposing factors  
symptoms  
test results  
diseases  
treatment outcomes

class labels for  
thousands of superpixels

Random variables  $X_1, \dots, X_n$  ~ binary valued distribution over  $2^n$  possible states

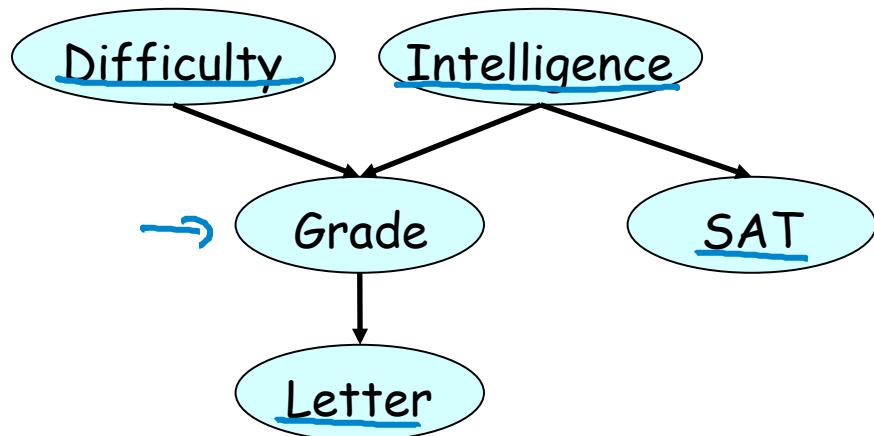
Joint distribution  $P(X_1, \dots, X_n)$

~~x... nodes~~

# Graphical Models

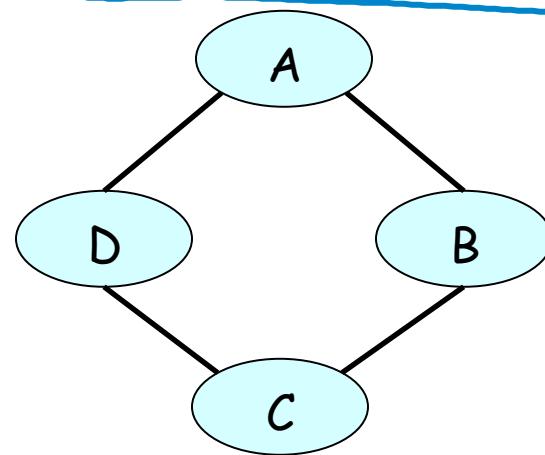
directed graph

## Bayesian networks



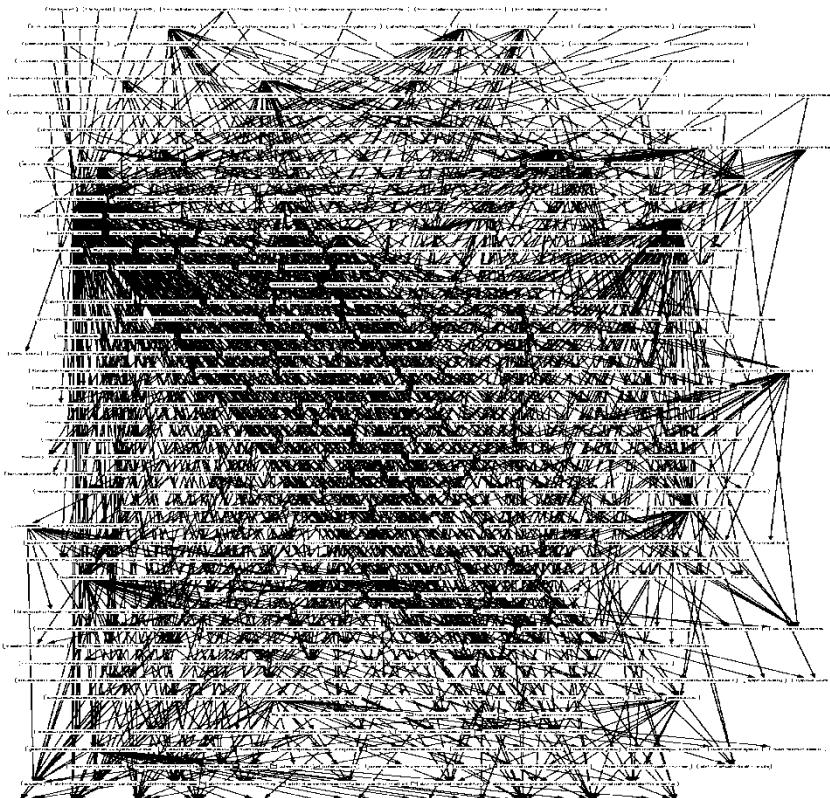
undirected graph

## Markov networks

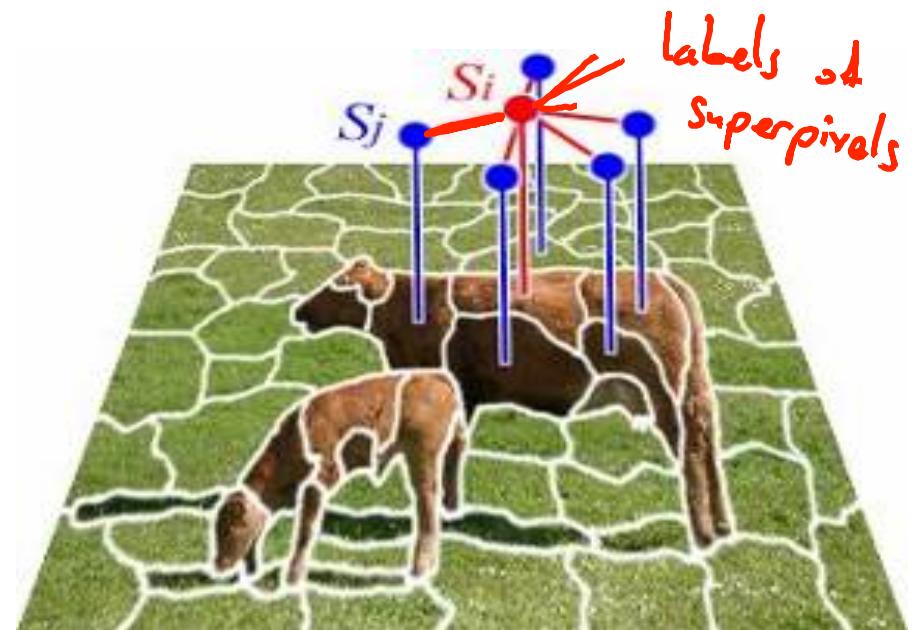


diag ~vis  
CP CS

# Graphical Models



M. Pradhan, G. Provan, B. Middleton, M. Henrion, UAI 94



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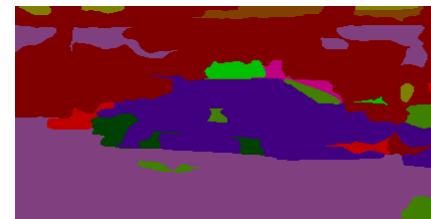
# Graphical Representation

- Intuitive & compact data structure
- Efficient reasoning using general-purpose algorithms
- Sparse parameterization
  - feasible elicitation  $\leftarrow$  *by hand*
  - learning from data  $\leftarrow$  *automatically*

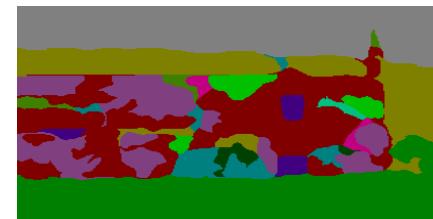
# Many Applications

- Medical diagnosis
- Fault diagnosis
- Natural language processing
- Traffic analysis
- Social network models
- Message decoding
- Computer vision
  - Image segmentation
  - 3D reconstruction
  - Holistic scene analysis
- Speech recognition
- Robot localization & mapping

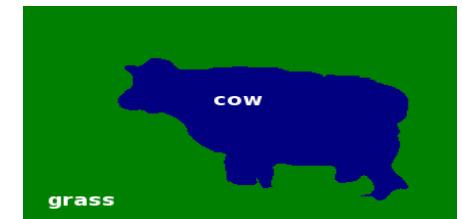
# Image Segmentation



superpixels



machine learning  
to separate superpixels



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Thanks to: Eric Horvitz, Microsoft Research

# Medical Diagnosis

Applet started

MS on □ ◀ ▶ X ?

ON STAGE ESSENTIALS COMMUNICATE FIND ✓ ?

OnParenting May 14 - May 20, 1997 Fidelity Investments® Our home on the web [is where] click here

cover contents news experts fun handbook talk find help feedback

There are two ways to search for specific information in OnParenting. In **Find by Word**, type the word(s) you want to find and get a list of titles relevant to that word. **Find by Symptom** will help you get information about children's symptoms. [Help](#) has tips to target your search.

**Describe the child**  
in the drop-down boxes at the right. Relevant information will appear below.

Age: Toddler Sex: Female  
Complaint: Abdominal pain

Localized pain: Can the child localize, or point to, the site of the pain?  
 No, unable to localize  
 Below the navel to the child's left  
 Above the child's navel  
 Either of the child's sides  
 Below the navel to the child's right  
 Above the navel to the child's right  
 Above the navel to the child's left  
 Don't Know

**Results so far**

Disorder	Relevance
Viral gastroenteritis	High
Psychosomatic pain	Medium
Urinary tract infection	Low
Other	Very Low

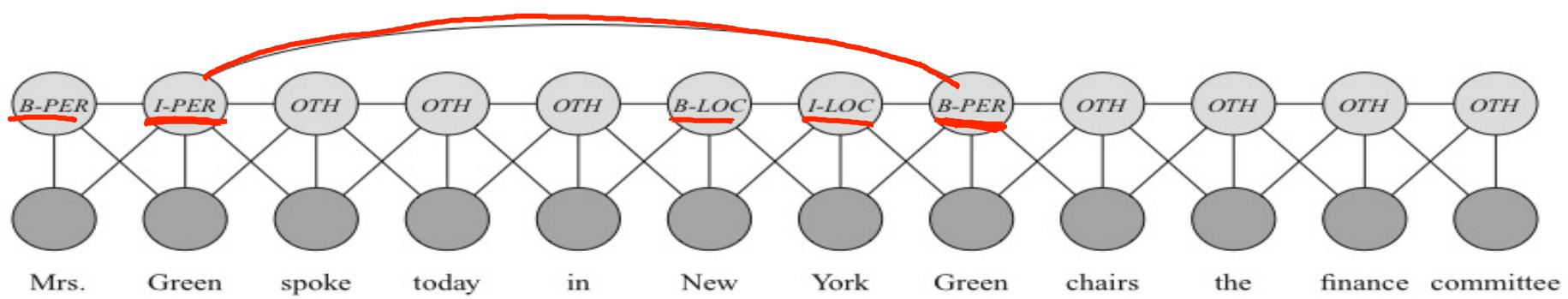
Start Over Review  
Next>> Finish



Daphne Koller

# Textual Information Extraction

Mrs. Green spoke today in New York. Green chairs the finance committee.  
*Person* *Location* *Person* *Organization*



# Multi-Sensor Integration: Traffic

Live Search Maps  
http://maps.live.com/#JnE9eXaud2FzaGluZ3RvbikYyU3ZXNzdC4wTdlcGcuMSzIYj000S45NTEyMTk5MDg2NjIN2UtNjkuNzg1MTU2MjUIN2UyMC44

Live Search Maps | MSN | Windows Live

Live Search | Businesses | People | Collections | Locations | Web

Share | Print

Washington, D.C.

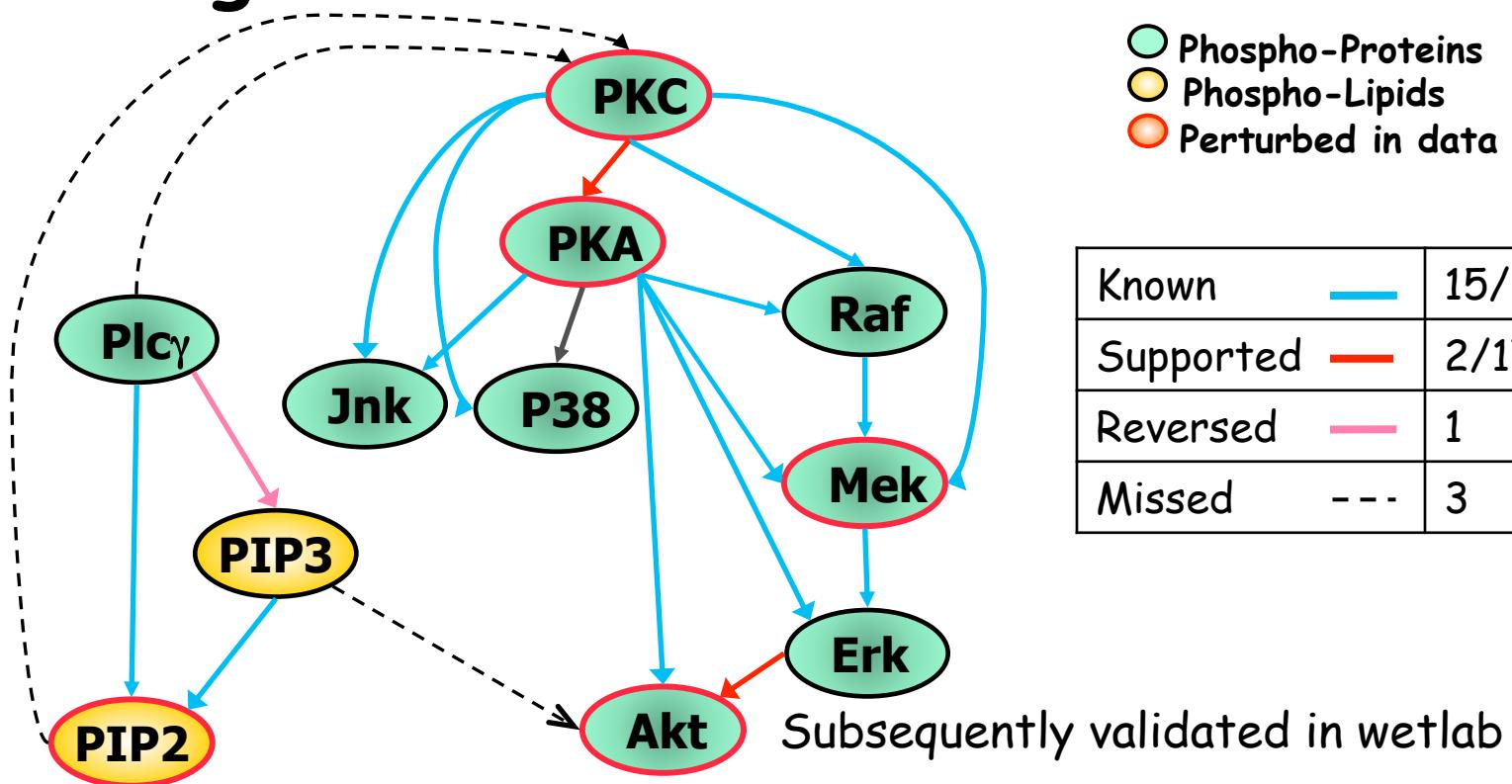
• I95 corridor experiment: accurate to  $\pm 5$  MPH in 85% of cases

• Fielded in 72 cities

Thanks to: Eric Horvitz, Microsoft Research

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# Biological Network Reconstruction



Causal protein-signaling networks derived from multiparameter single-cell data  
Sachs et al., *Science* 2005

Daphne Koller

# Overview

- Representation
  - Directed and undirected
  - Temporal and plate models
- Inference *reasoning*
  - Exact and approximate
  - Decision making
- Learning
  - Parameters and structure
  - With and without complete data