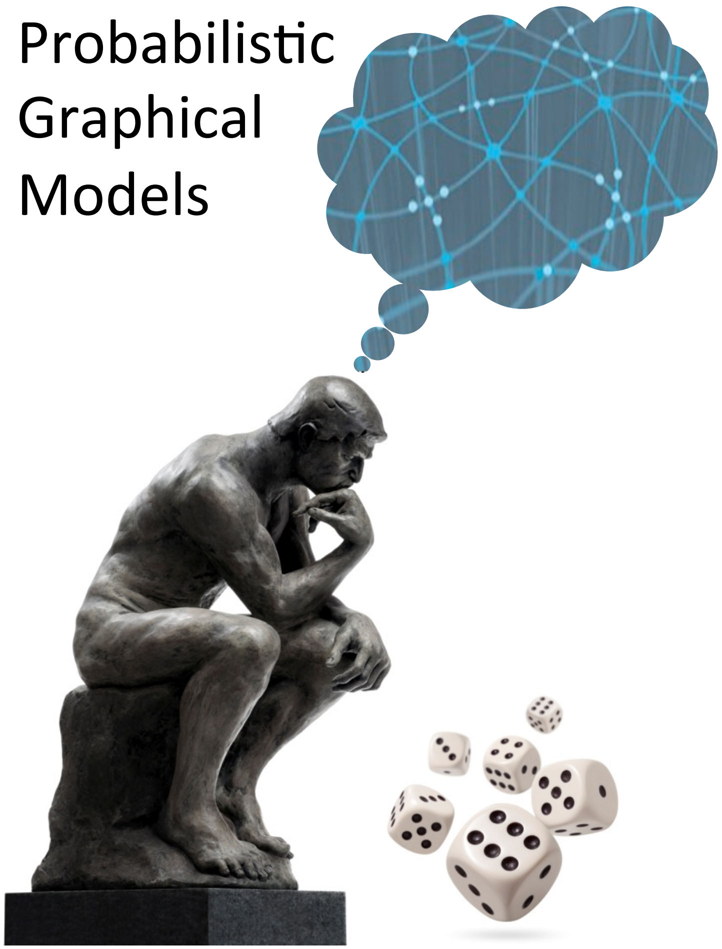


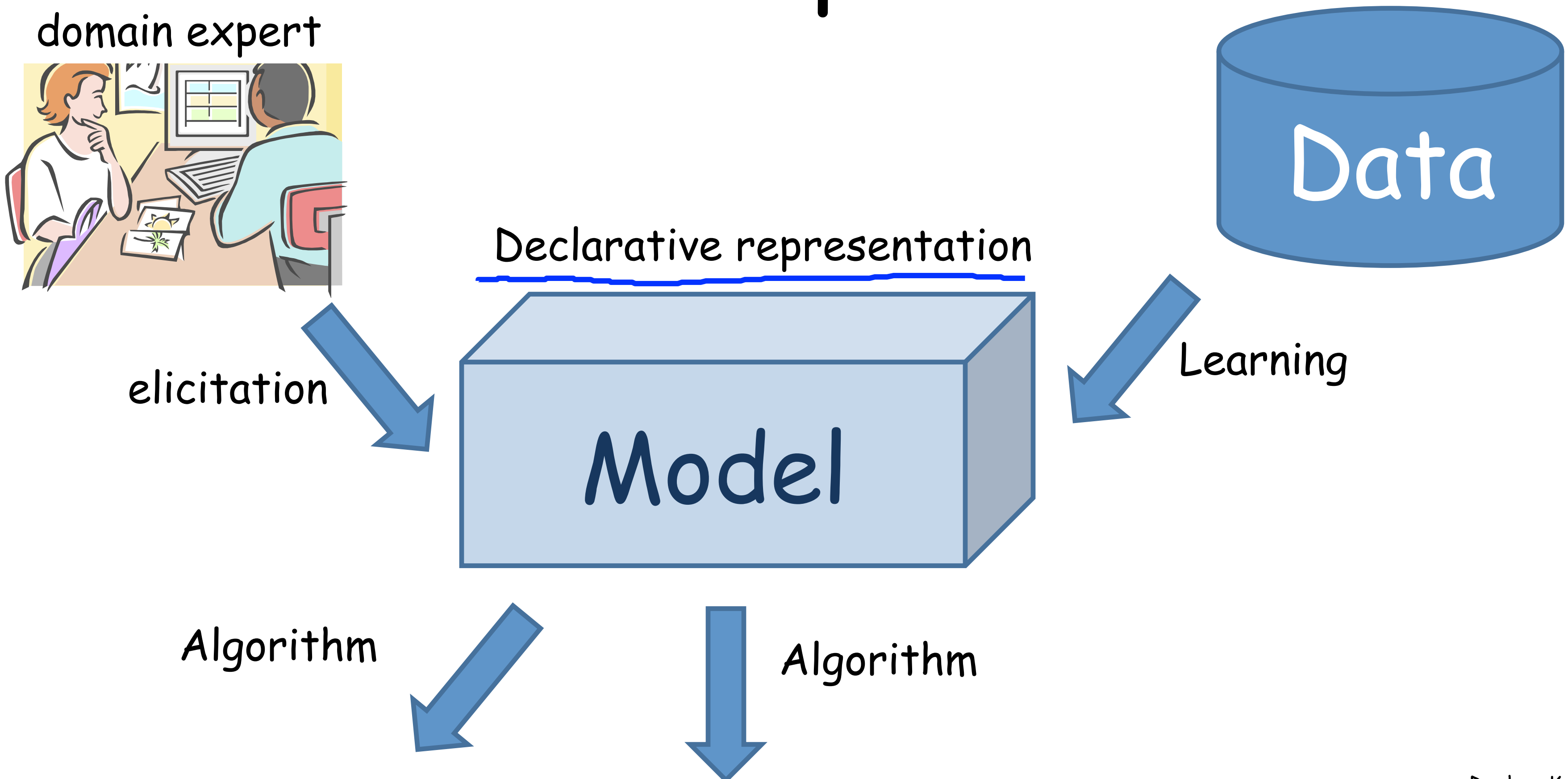
Summary

Probabilistic Graphical Models

Why PGMs?

- PGMs are the marriage of statistics and computer science
  - Statistics: Sound probabilistic foundations
  - Computer science: Data structures and algorithms for exploiting them

Declarative Representation



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When PGMs?

- When we have noisy data and uncertainty
- When we have lots of prior knowledge
- When we wish to reason about multiple variables
- When we want to construct richly structured models from modular building blocks

Intertwined Design Choices

- Representation
  - affects cost of inference & learning
- Inference algorithm
  - Used as a subroutine in learning
  - Some are only usable in certain types of models
- Learning algorithm
  - Learnability imposes modeling constraints

Example: Image Segmentation

- BNs vs MRFs vs CRFs
  - Naturalness of model
  - Using rich features
  - Inference costs
  - Training cost
  - Learn with missing data

features ×

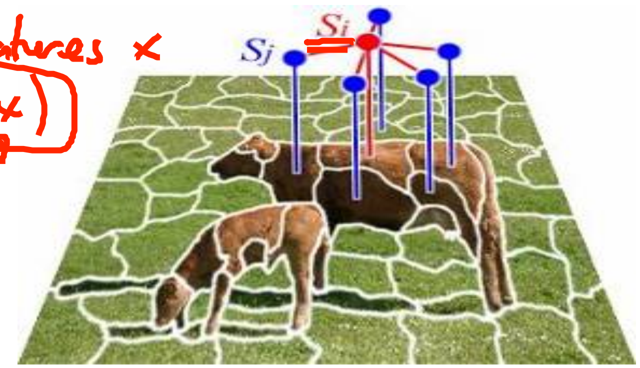
$\boxed{P(S|X)}$

latent

correlated

(associative, regular)

✗ CRF →



adjacent pixels have same labels

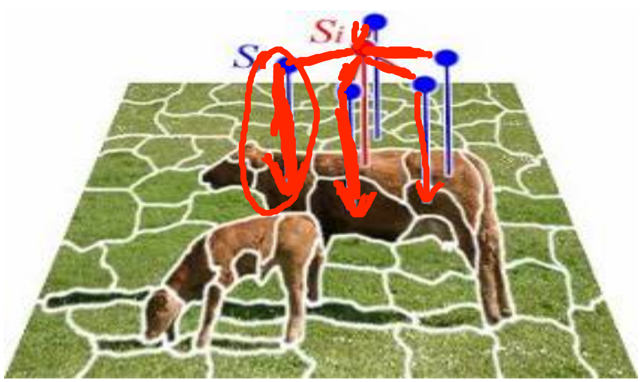
cows are on top of grass

learn to segment from unsupervised data

Mix & Match: Modeling

- Mix directed & undirected edges
- E.g., image segmentation from unlabeled images
  - Undirected edges over labels S – natural lack of directionality
  - Directed for $P(X_i \mid S_i)$ – easy learning (w/o inference)

explain images using segment characteristics



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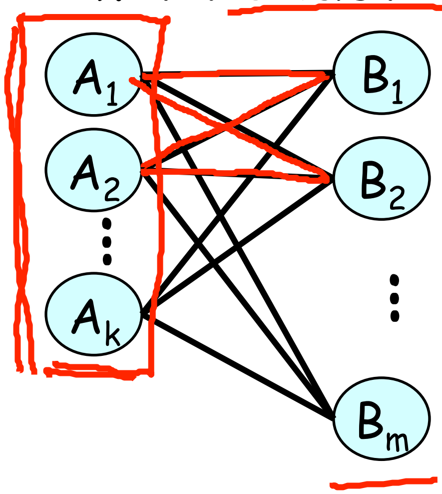
Mix & Match: Inference

- Apply different inference algorithms to different parts of model
- E.g., combine approximate inference (BP or MCMC) with exact inference over subsets of variables



for each $a_1[m], \ldots, a_k[m]$
distribution over
B's

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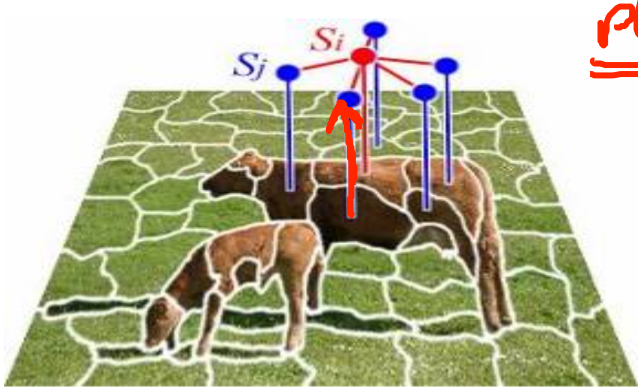
Mix & Match: Learning

- Apply different learning algorithms to different parts of model
- E.g., combine high-accuracy, easily-trained model (e.g., SVM) for node potentials P(S | X) with CRF learning for higher-order potentials

P(s|x)



Summary

- Integrated framework for reasoning and learning in complex, uncertain domains
  - Large bag of tools within single framework
- Used in a huge range of applications
- Much work to be done, both on applications and on foundational methods