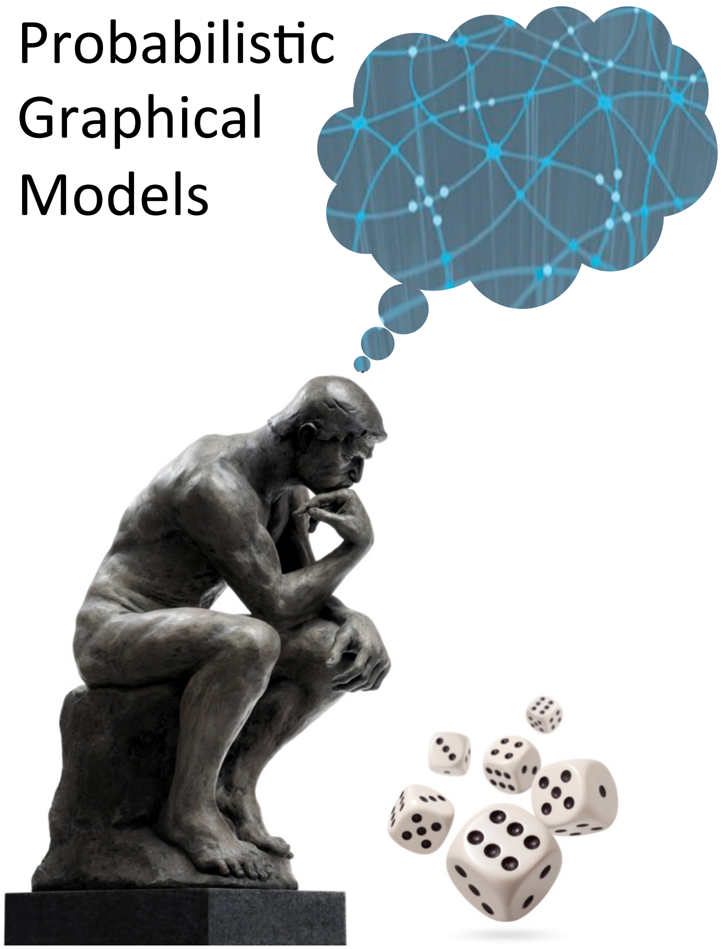


Representation

Markov Networks

Conditional Random Fields

Motivation

- Observed variables $\underline{X}$
- Target variables $\underline{Y}$

$X \longrightarrow Y$

$P(X, Y)$ joint

$P(Y \mid X)$ conditional

	X		Y
image segmentation	pixel values & processed feature.	$\rightarrow$	pixel labels
text processing	words in a sentence		parts of speech

CRF Representation

$\phi_1(\boldsymbol{D}_1), \ldots, \phi_k(\boldsymbol{D}_k)$ Gibbs did

$\tilde{P}(\bar{X}, \bar{Y}) = \prod_{i=1}^{k} \phi_i(\bar{D}_i)$ unnormalized measure

$Z(\bar{X}) = \sum_{\bar{Y}} \tilde{P}(\bar{X}, \bar{Y})$ different $Z(\bar{X})$ for every assignment to the obs. variables $\bar{X}$

$P(\bar{Y} \mid \bar{X}) = \frac{1}{Z(\bar{X})} \tilde{P}(\bar{X}, \bar{Y})$ $\left(\sum_{\bar{Y}} P(\bar{Y} \mid \bar{X}) = 1 \text{ for all } \bar{X} \right)$

CRFs and Logistic Model

$$\boxed{\phi_i(X_i, Y) = \exp\{w_i \mathbf{1}\{X_i = 1, Y = 1\}\}}$$

$$\phi_i(x_i, Y=1) = \exp\{w_i x_i\}$$

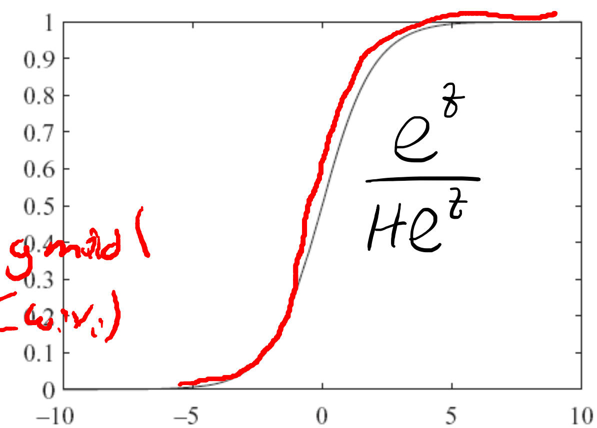
$$\phi_i(x_i, Y=0) = 1$$

$$\tilde{P}(Y=1, x_1, \ldots, x_n) = \exp\left(\sum_i w_i x_i\right)$$

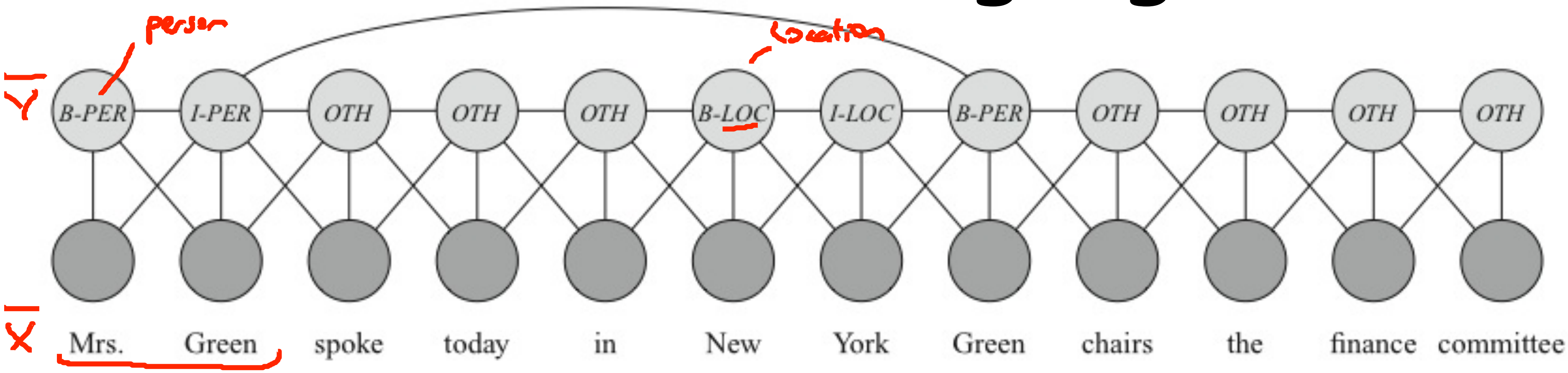
$$\tilde{P}(Y=0, x_1, \ldots, x_n) = 1$$

$$P(Y=1 \mid x_1, \ldots, x_n) = \frac{\exp\left(\sum_i w_i x_i\right)}{1 + \exp\left(\sum_i w_i x_i\right)} = \text{sigmoid}\left(\sum w_i x_i\right)$$

$$\frac{P(Y=1, X_1 \ldots X_n)}{P(X_1 \ldots X_n)}$$



CRFs for Language



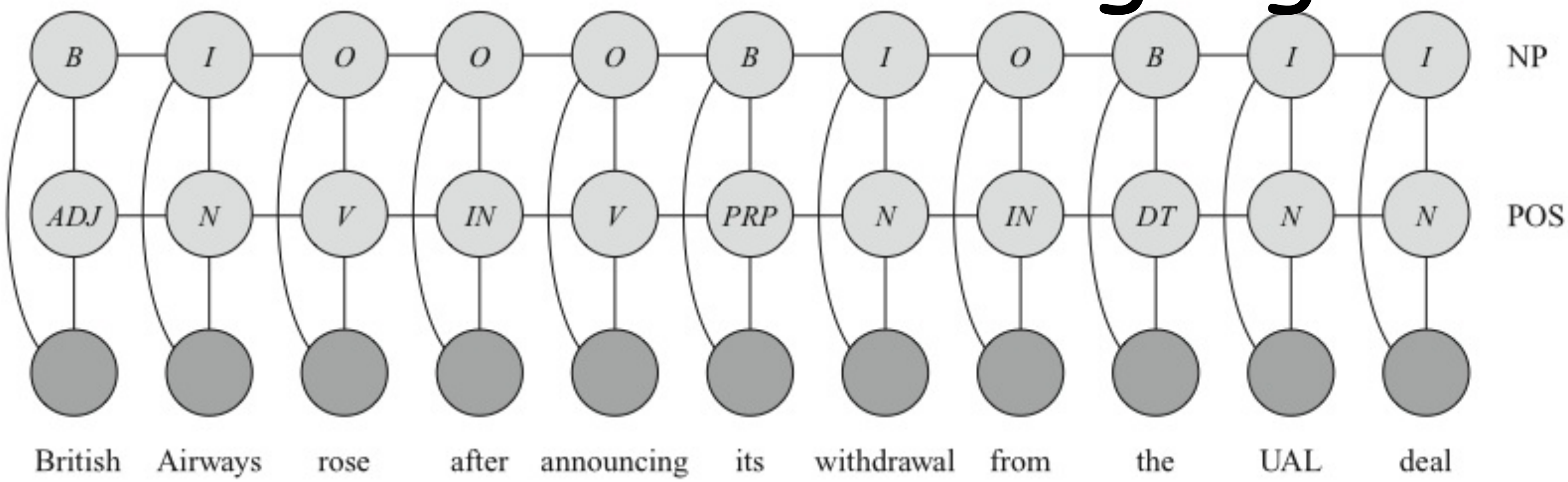
Features: word capitalized, word in atlas or name list, previous word is "Mrs", next word is "Times", …

$\tilde{P}(\bar{X}, \bar{Y})$

$\Rightarrow P(\bar{Y} \mid \bar{X})$

Daphne Koller

More CRFs for Language



KEY

B	Begin noun phrase	*V*	Verb
I	Within noun phrase	*IN*	Preposition
O	Not a noun phrase	*PRP*	Possesive pronoun
N	Noun	*DT*	Determiner (e.g., a, an, the)
ADJ	Adiective		

Daphne Koller

Summary

- A CRF is parameterized the same as a Gibbs distribution, but normalized differently
- Don't need to model distribution over variables we don't care about
- Allows models with highly expressive features, without worrying about wrong independencies