

## Sequences II



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**CS1114**  
**<http://cs1114.cs.cornell.edu>**



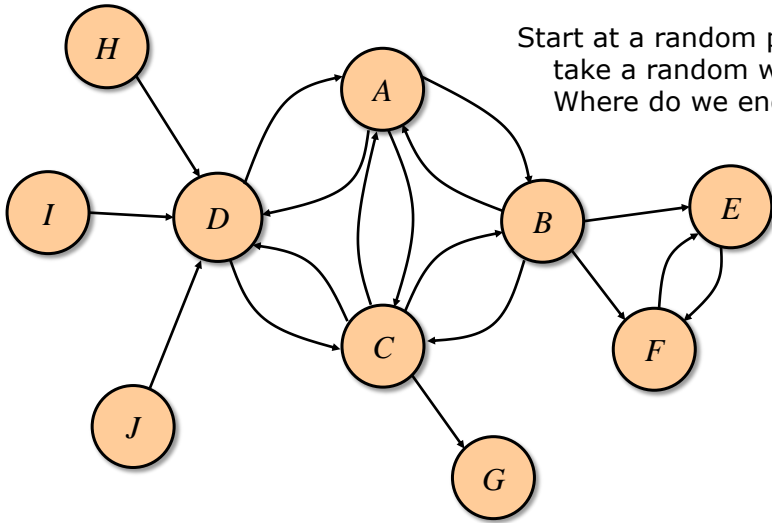
Cornell University  
Computer Science

## Administrivia

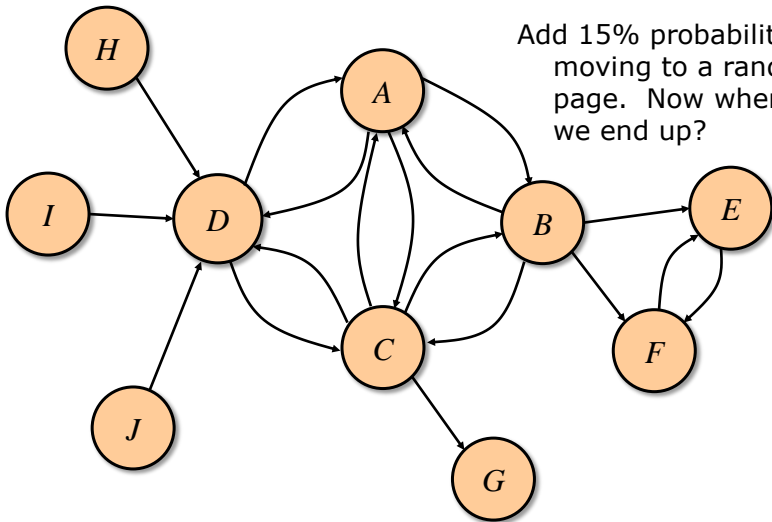
- Assignments:
  - A5P2 due on Friday
- Quiz Tuesday, 4/24
- Final project proposals due on CMS by this Thursday



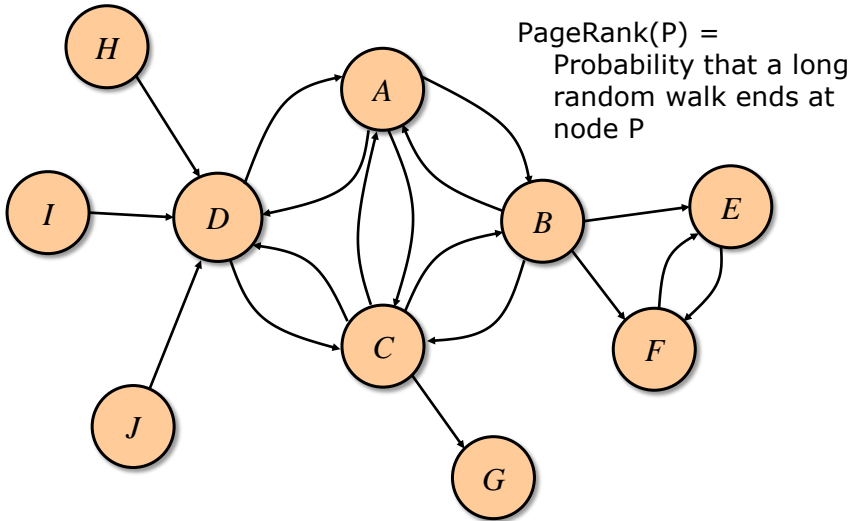
# Google's PageRank



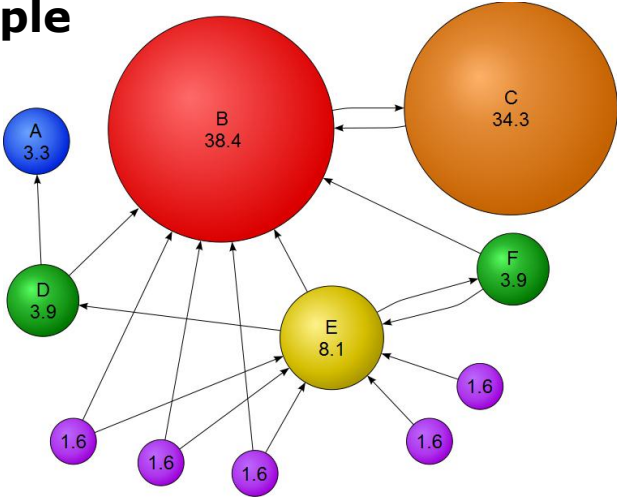
# Google's PageRank



# Google's PageRank

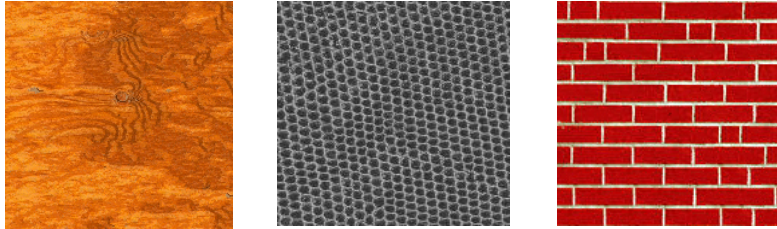


## Example



(The ranks are an eigenvector of the transition matrix)

# Modeling Texture

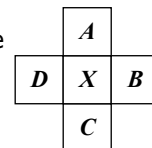


- What is texture?
  - An image obeying some statistical properties
  - Similar structures repeated over and over again
  - Often has some degree of randomness

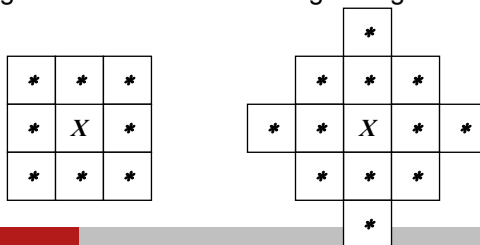
## Markov Random Field

- A Markov random field (MRF)
  - generalization of Markov chains to two or more dimensions.
- First-order MRF:
  - probability that pixel  $X$  takes a certain value given the values of neighbors  $A$ ,  $B$ ,  $C$ , and  $D$ :

$$P(X|A, B, C, D)$$



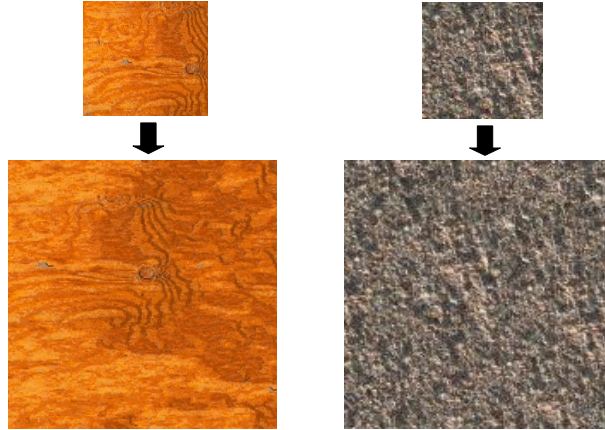
- Higher order MRF's have larger neighborhoods



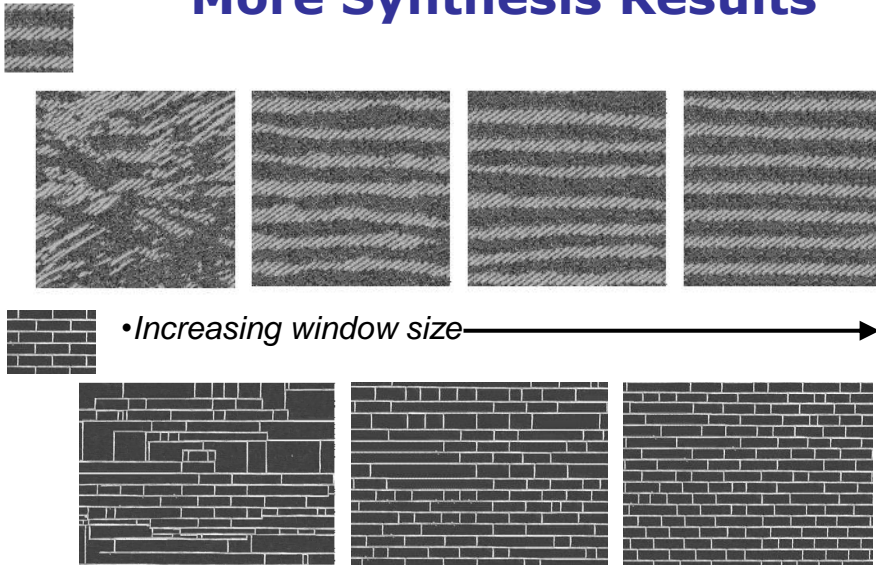
# Texture Synthesis

[Efros & Leung, ICCV 99]

- Can apply 2D version of text synthesis

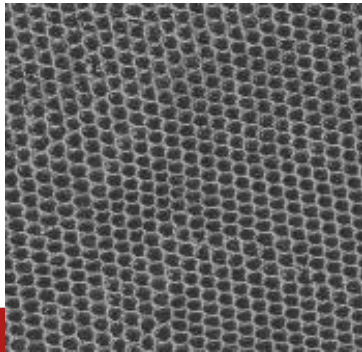
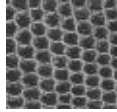


## More Synthesis Results

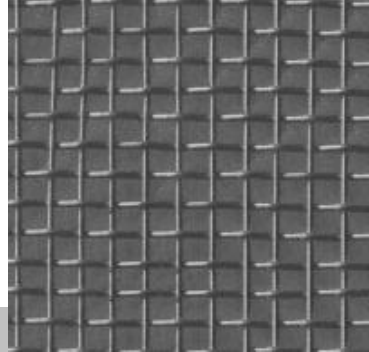
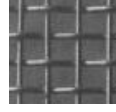


# More Results

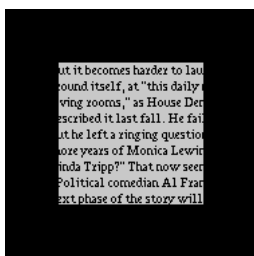
•reptile skin



•aluminum wire

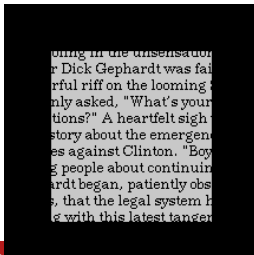


# Image-Based Text Synthesis



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...ving rooms," as House De...  
...scribed it last fall. He fai...  
...the left a ringing questio...  
...ore years of Monica Lewin...  
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...Political comedian Al Fran...  
...ext phase of the story will

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...ly asked, "What's your...  
...ntions?" A heartfelt sigh vatfi...  
...story about the emergen...  
...es against Clinton. "Boyoatella...  
...ig people about continuin...  
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...ams, that the legal system hur...  
...bag with this latest tanger...  
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## Author recognition

- Simple problem:  
Given two Markov chains, say *Austen* ( $A$ ) and *Dickens* ( $D$ ), and a string  $s$  (with  $n$  words), how do we decide whether  $A$  or  $D$  wrote  $s$ ?
- Idea: For both  $A$  and  $D$ , compute the probability that a random walk of length  $n$  generates  $s$



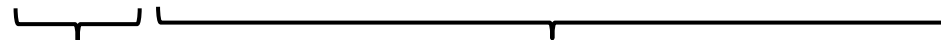
## Probability of a sequence

- What is the probability of a given  $n$ -length sequence  $s$ ?

$$s = s_1 s_2 s_3 \dots s_n$$

- Probability of generating  $s$  = the product of transition probabilities:

$$\Pr(S_1 = s_1) \Pr(S_2 = s_2 | S_1 = s_1) \Pr(S_3 = s_3 | S_2 = s_2) \dots \Pr(S_n = s_n | S_{n-1} = s_{n-1})$$



Probability that  
a sequence  
starts with  $s_1$

Transition probabilities



## Likelihood

- Compute this probability for  $A$  and  $D$

$\Pr(s|A)$   
“likelihood” of  $A$

$\Pr(s|A) > \Pr(s|D)$   
*Jane Austen wrote  $s$*

$\Pr(s|D)$   
“likelihood” of  $D$

$\Pr(s|A) < \Pr(s|D)$   
*Charles Dickens wrote  $s$*

$\Pr(s|A) = \Pr(s|D)$   
???



## Problems with likelihood

1. Most strings of text (of significant length) have probability zero
    - Why?
  2. Even if it's not zero, it's probably extremely small
    - What's  $0.01 * 0.01 * 0.01 * \dots (x200) \dots * 0.01$ ?
    - According to Matlab, zero
- How can we fix these problems?

