

## Announcements

### Final

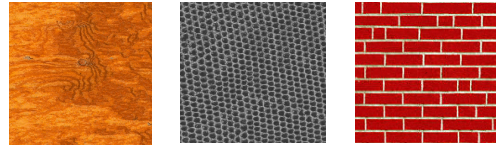
- Monday 10:30-12:20, in this room
- Closed book/notes
- Comprehensive (through today)
- Review today

### Project 3 artifacts

### Evals

- at end of class

## Modeling Texture



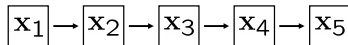
What is texture?

How can we model it?

## Markov Chains

### Markov Chain

- a *sequence* of random variables  $X_1, X_2, \dots, X_n$
- $X_t$  is the **state** of the model at time  $t$



- **Markov assumption**: each state is dependent only on the previous one
  - dependency given by a **conditional probability**:

$$p(X_t | X_{t-1})$$

- The above is actually a *first-order* Markov chain
- An  $N$ 'th-order Markov chain:

$$p(X_t | X_{t-1}, \dots, X_{t-N})$$

## Markov Chain Example: Text

"A dog is a man's best friend. It's a dog eat dog world out there."

a	2/3	1/3											
dog		1/3				1/3	1/3						
is	1												
man's													
best				1									
friend					1								1
it's	1												
eat		1											
world										1			
out											1		
there												1	
.						1							
a	dog	is	man's	best	friend	it's	eat	world	out	there	.		

$X_{t-1}$   $p(X_t | X_{t-1})$

$X_t$

## Text synthesis

Create plausible looking poetry, love letters, term papers, etc.

### Most basic algorithm

1. Build probability histogram
  - find all blocks of N consecutive words/letters in training documents
  - compute probability of occurrence  $p(x_t | x_{t-1}, \dots, x_{t-(n-1)})$
2. Given words  $x_1, x_2, \dots, x_{k-1}$ 
  - compute  $x_k$  by sampling from  $p(x_t | x_{t-1}, \dots, x_{t-(n-1)})$

Example on board...

[Scientific American, June 1989, Dewdney]

### "I Spent an Interesting Evening Recently with a Grain of Salt"

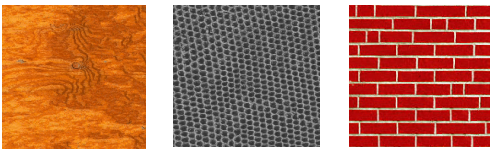
- Mark V. Shaney

(computer-generated contributor to UseNet News group called net.singles)

Output of 2nd order word-level Markov Chain after training on 90,000 word philosophical essay:

*"Perhaps only the allegory of simulation is unendurable--more cruel than Artaud's Theatre of Cruelty, which was the first to practice deterrence, abstraction, disconnection, deterritorialisation, etc.; and if it were our own past. We are witnessing the end of the negative form. But nothing separates one pole from the very swing of voting "rights" to electoral..."*

## 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)

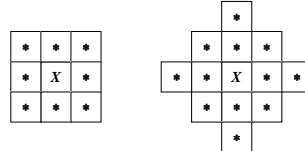
- generalization of Markov chains to two or more dimensions.

### First-order MRF:

- probability that pixel  $X$  takes a certain value given the values of neighbors  $A, B, C,$  and  $D$ :

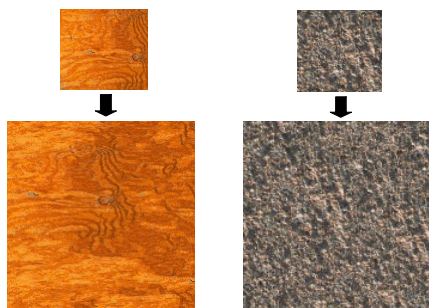
$$P(X|A, B, C, D)$$

- Higher order MRF's have larger neighborhoods

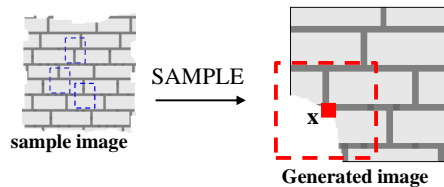


## Texture Synthesis [\[Efros & Leung, ICCV 99\]](#)

Can apply 2D version of text synthesis



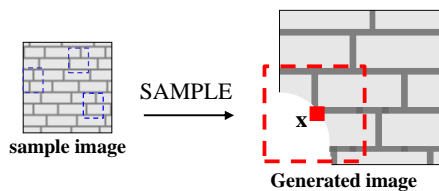
## Synthesizing One Pixel



- What is  $P(x|\text{neighborhood of pixels around } x)$  ?
- Find all the windows in the image that match the neighborhood
  - consider only pixels in the neighborhood that are already filled in
- To synthesize  $x$ 
  - pick one matching window at random
  - assign  $x$  to be the center pixel of that window

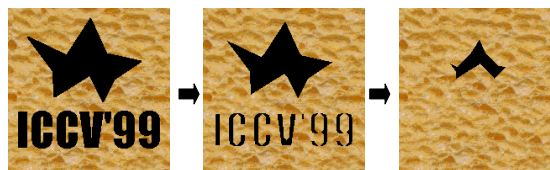
Slides courtesy of [Alyosha Efros](#)

## Really Synthesizing One Pixel



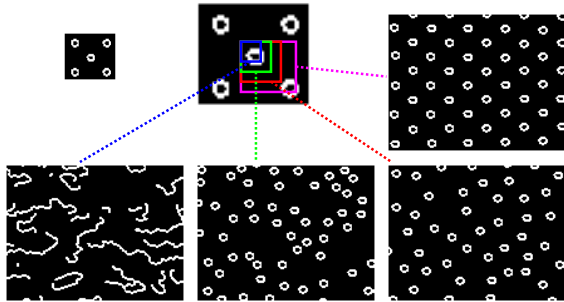
- An exact neighbourhood match might not be present
- So we find the **best** matches using SSD error and randomly choose between them, preferring better matches with higher probability

## Growing Texture

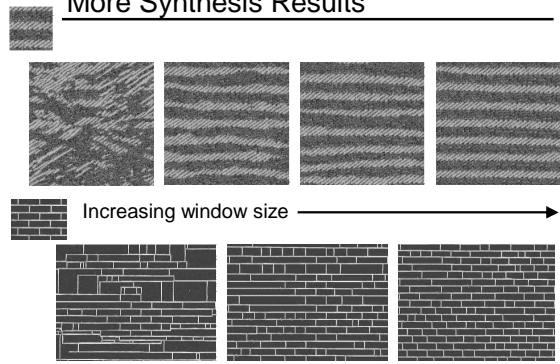


- Starting from the initial image, "grow" the texture one pixel at a time

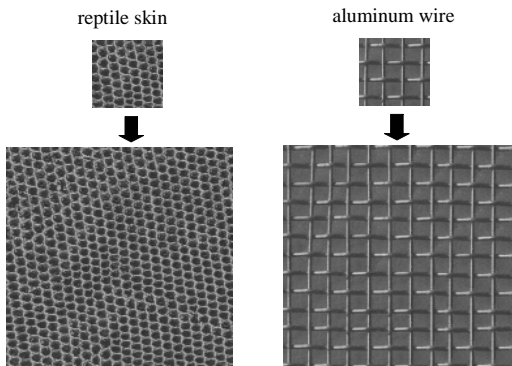
### Window Size Controls Regularity



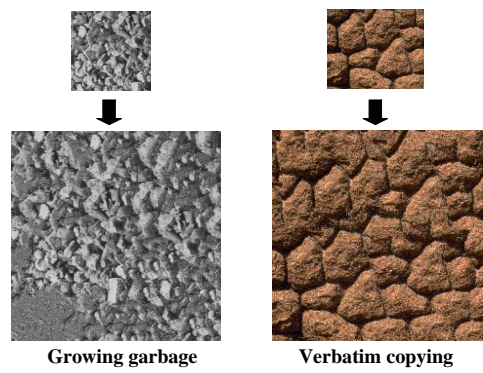
### More Synthesis Results



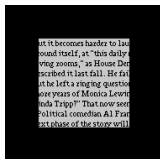
### More Results



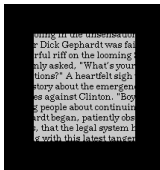
### Failure Cases



## Image-Based Text Synthesis



it becomes harder to find  
 found itself, at this daily  
 ing rooms, as House de-  
 scribed it last fall. He had  
 the left a ringing question  
 se years of Monica Lewin-  
 s Trip? That now seems hard  
 olitical conches. At Pan-  
 of new

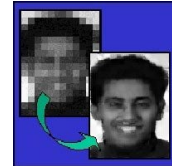


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## Applications of Texture Modeling

### Super-resolution

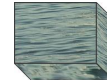
- [Freeman & Pasztor, 1999](#)
- [Baker & Kanade, 2000](#)



### Image/video compression

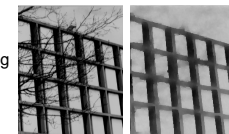
#### Video Textures

- [Wei & Levoy, 2000](#)
- [Schodt et al., 2000](#)



### Texture recognition, segmentation

- [DeBonet](#)



### Restoration

- removing scratches, holes, filtering
- [Zhu et al.](#)

### Art/entertainment