

## Procedural Modeling

## Procedural Models

- Subdivision Surfaces.
- Sweeps.
- Fractals.
- Grammar-based modeling.
  - L-systems.
- Cellular Automata.
  - Lattice Boltzman Machine.

## L-systems

- A powerful procedural technique
- Based on grammars
  - Rewriting rules
- Most popular for plants
- Recent applications:
  - Cities
  - Feathers

## Plants

- Complex systems
- Often, have a well defined structure
  - Trunk
  - Big branches
  - Little branches
  - Leaves
- High degree of “recursiveness”
  - Grammars/compiler are good with this.

## Grammar-Based Models

- Generate description of geometric model by applying production rules

$S \rightarrow AB$
$A \rightarrow Ba \mid a$
$B \rightarrow Ab \mid b$

ab  
bab  
baab  
abaab

## Grammar-based models

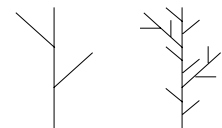
- Useful for modeling plants.

$F \rightarrow F[RF]F[LF]F,$

where  $F$ : forward

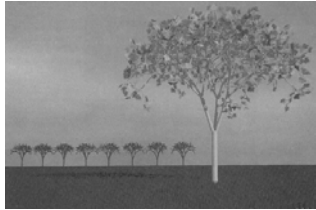
$R$ : turn right

$L$ : turn left.



## Grammar-based models

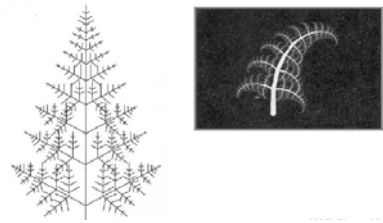
- Apply the rule randomly to occurrences of  $F$ .  
 $F \rightarrow F^*[RF]F^*[LF]F^*$ .



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## Grammar-based models



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## Grammar-based model: L-systems

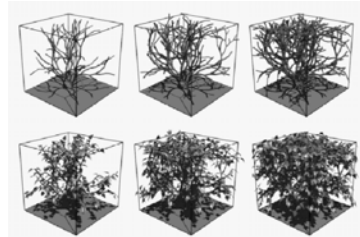
- grammar-based fractal-like models
- describe an object by a string of symbols and provide a set of production rules
- incorporate notions such as branching, pruning, ...
- can also vary objects by randomly applying rules
- demo:  
<http://www.cpsc.ucalgary.ca/Redirect/bmv/java/LSystems/LSys.html>



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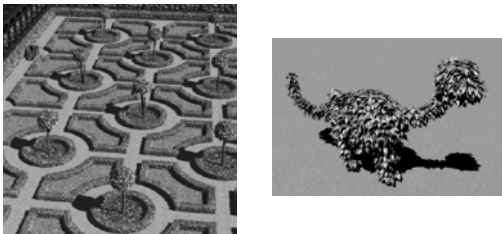
## More examples



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## More examples



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## Procedural Modeling: summary

- Procedural techniques are very powerful
- Use with care
  - Physical validation is rare
- For some objects, procedure is the answer
  - Plants
- Can complement physics-based methods
  - Adding high frequency details
- General recommendation: add noise to your models to make them more “natural”

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## Cellular automata

- Simple example - game of life
- The rules:
  - Binary state on a 2D grid: cell / no cell
  - If too few or too many cells surround a cell, it dies
  - If two cells surround empty space, a cell is born
- Very simple rules produce complex behavior
  - Stable patterns
  - Moving stable patterns
  - Oscillations

## Complex cellular automata

- Can have more than one cell system interacting
- Rules can be arbitrary
  - Model the needed behavior
- The result is (usually) a distribution of some property
  - Binary result, need extra step
- The art is in creating the rules
  - Take from differential equations
  - Take from general intuition
    - Too many cell -> overcrowding -> dies

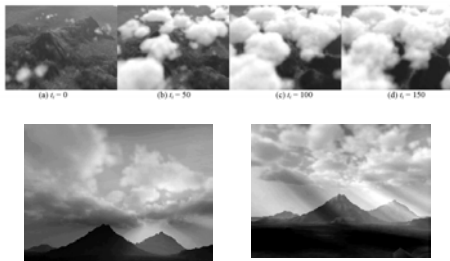
## Example: clouds

- Need cloud density in 3D
- 3 binary variables
  - Cloud
  - Humidity
  - Action
- General idea:
  - Action tells to create cloud
  - Cloud particle formed if there is humidity
  - Clouds grow, so set action to 1 if there is action nearby

## Cloud forming rules

- $Hum = (hum) \& (!act)$ 
  - Action removes humidity
- $Cl_d = (cld) | (act)$ 
  - Form cloud particle if action
- $Act = (!act) \& (hum) \& f(surround\ action)$
- $f = |$  of all act in a template
- Extinction: do with some probabilities
  - Clear cld
  - Introduce new hum
  - Start new action

## Cloud results (Dobashi et. al.)



## Lattice Boltzman Machine

- Extension of cellular automata.
- Can simulate more natural phenomena besides clouds.

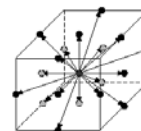


Figure 3: The D3Q19 lattice geometry

## Modeling—summary

How do we ...

- Represent 3D objects in a computer?
- Construct such representations quickly and/or automatically with a computer?
- Manipulate 3D objects with a computer?

## Model Construction

- Interactive modeling tools
  - CAD programs
  - Subdivision surface editors :)
- Scanning tools
  - CT, MRI, laser, magnetic, robotic arm, etc.
- Computer vision
  - Stereo, motion, etc.
- Procedural generation
  - Sweeps, fractals, grammars
- Physics-based modeling