Adding Visual Realism

- Road to Point Reyes (see figure)
    - Texture Mapping
    - Fractals
    - Particle Systems

Texture Mapping

- Avoid boring, flat, smooth surfaces
- Avoid actually modeling each surface detail
- Have patch of texture defined - Brodatz textures
    - Map it all over the object
- Two parts:
    - 1) Texture mapping
        - eg image distortion
    - 2) Texture filtering
        - eg antialiasing
- Texture patch application:
    - 1) Tiling
        - eg light and dark marble tiles
            - repetitive pattern on bark
    - 2) Nontiling
        - eg billboard, painting

$$\begin{tikzcd}
\boxed{\begin{array}{l}\text{Texture Space:}\\ \text{(s, t) Array}\\ \text{Coordinates}\end{array}} \arrow[r, leftrightarrow] & \boxed{\begin{array}{l}\text{Object Space:}\\ \text{(u,v) Surface}\\ \text{Parameters}\end{array}} \arrow[r, leftrightarrow] & \boxed{\begin{array}{l}\text{Image Space:}\\ \text{(x,y) Pixel}\\ \text{Coordinates}\end{array}}
\end{tikzcd}$$

Texture-Surface Transformation

Viewing and Projection Transformation

Can do texture mapping in either direction:

1) texture scanning

texture space to object space to image space

2) pixel-order scanning

image space to object space to texture space

Texture to object space

parametric linear functions

$u = a_u s + b_u t + c_u$

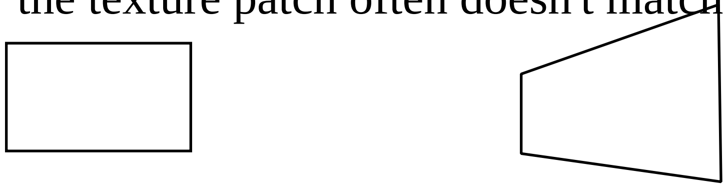
$v = a_v s + b_v t + c_u$

Object to image space

regular viewing and projection transformations concatenated

Problem with mapping texture space to image space

the texture patch often doesn't match up with the pixel boundaries



Mapping from image space to texture space

Disadvantage:

Must compute inverse to the viewing and projection transformations

Advantage:

Don't need to subdivide pixels

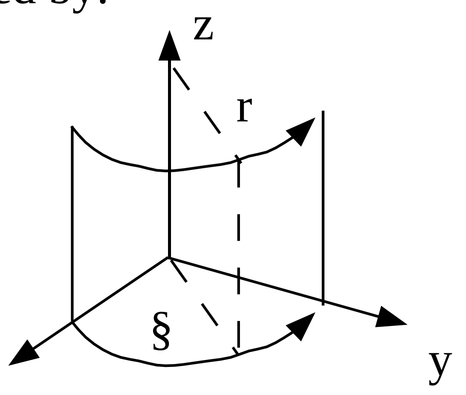
Can easily incorporate image processing - eg filtering

Example:

Map texture onto cylindrical surface defined by:

u = §; v = z

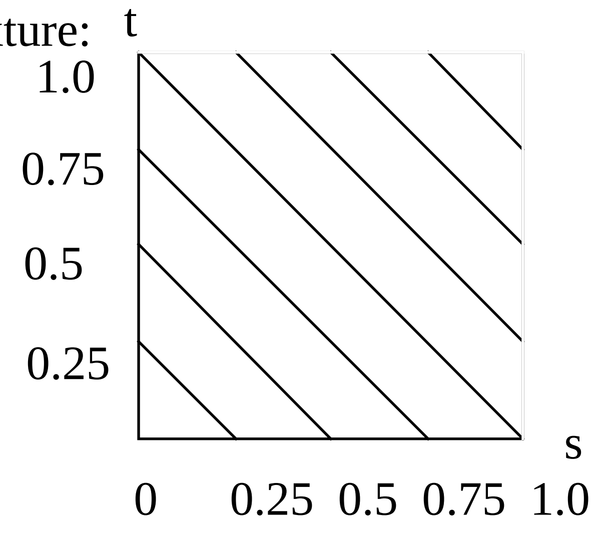
0 ² § ² 1/2,0 ² z ² 1



In x,y,z:

x = r cos u; y = r sin u; z =vx

Texture:



Map texture array to the surface

pattern origin to lower left corner

$u = s^1/2;$ $v = t$

Select viewing position and apply inverse transformation

Map image coordinates to object space

$u = \tan^{-1}(y/x);$ $v = z;$

Map object space to texture space

$s = 2u/^1;$ $t = v;$

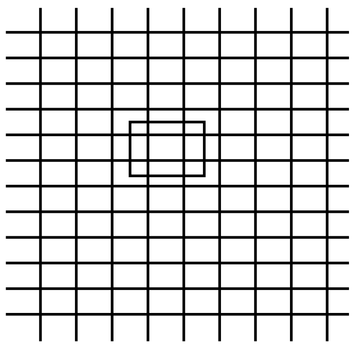
Antialiasing:

Why may need to do it?

Interference of sampling rate due to pixel spacing and texture pattern

How do it?

One simple way: pyramid weighted filtering



Project larger pixel area from image space

Use pyramid weighting

Fractals

- Man-made Objects
    - Flat surfaces
    - Smooth curved surfaces
- Objects in Nature
    - Rough jagged edges
    - eg lightening bolt
        - nice to be able to specify just the ends points and not each little jag
- Get roughness and jagginess using fractals
- Fractals are self-similar

Start with Artificial Fractals

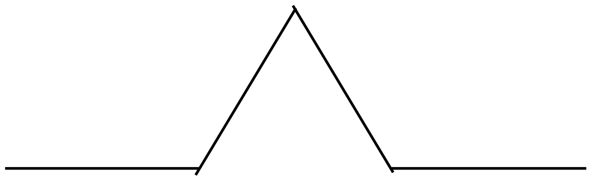
- Recursively defined curves

Koch Curves - (1904 - Sweden - Helge von Koch)

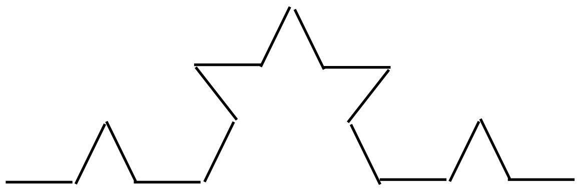
Infinite length within a finite area

K_0

K_1



K_2



Formation Process for K_i from K_{i-1}

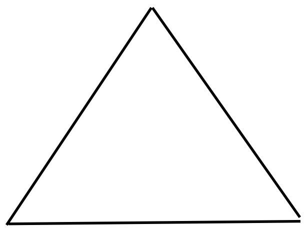
For each straight line at K_{i-1} (of length L)

Break line into thirds (of length L/3)

Replace middle third with two lines of length L/3

with 60 degree angle between first new line and the original line, and second new line joining up two unattached ends

Start with a triangle, get Koch Snowflake



Consider the length of K_0 to be 1

Then $|K_0| = ?$

$|K_1| = ?$

$|K_i| = (4/3)^i$

As i goes to infinity, $|K_i|$ goes to infinity

But the whole thing is still within a finite area

Look at objects of this nature as having a dimension

greater than a line (1)

but less than a plane (2)

That is a fractional dimensional object

fractal

This new dimension is called the Hausdorff-Besikovich dimension, D

$D = \log (N) / \log (1/S)$

where N is the number of line segments going from one stage to the next

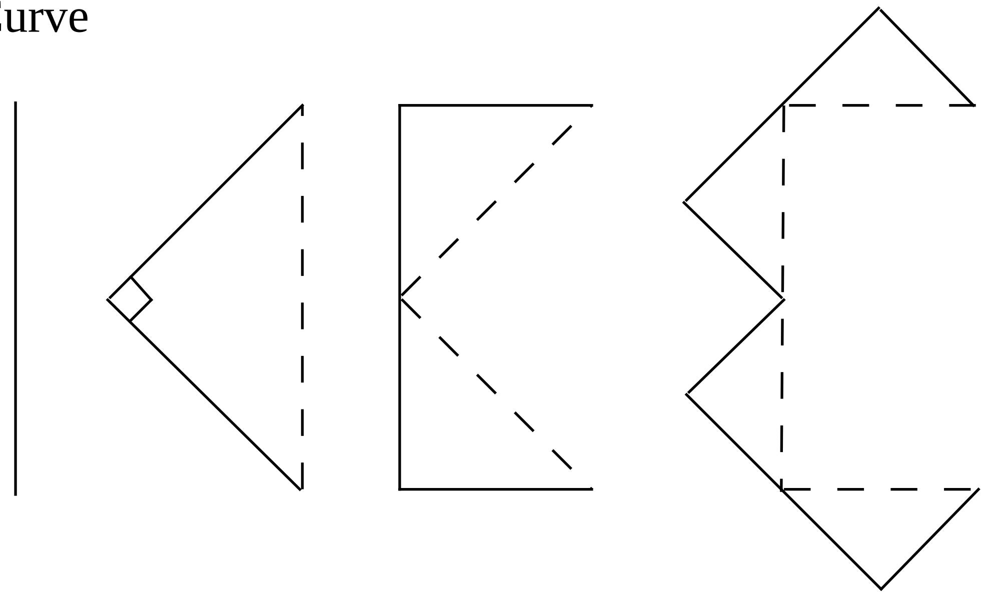
and S is the length of each segment, relative to the length of segments in the previous level

For Koch Curve:

$N = 4$; $S = 1/3$; $D = \log 4/ \log 3 = 1.2619$

Other artificial fractals:

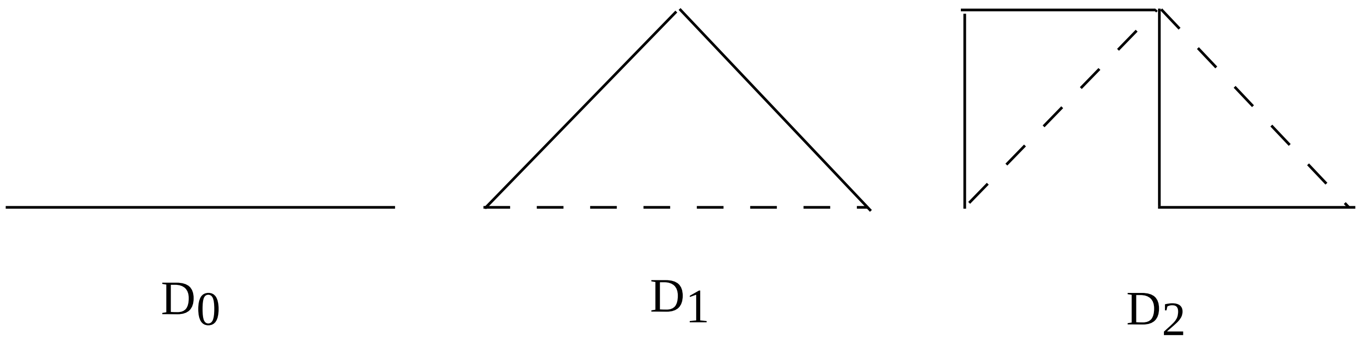
C-Curve

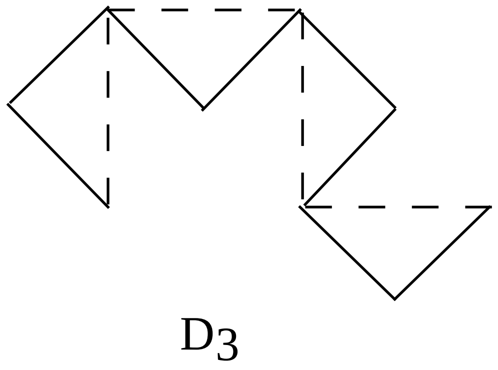


N = 2, S = 1/Ã2 D = log 2 / log Ã2 = 2

(see figure)

Dragon Curve





One elbow up,
the next down

N = ?; S = ?; D = ?

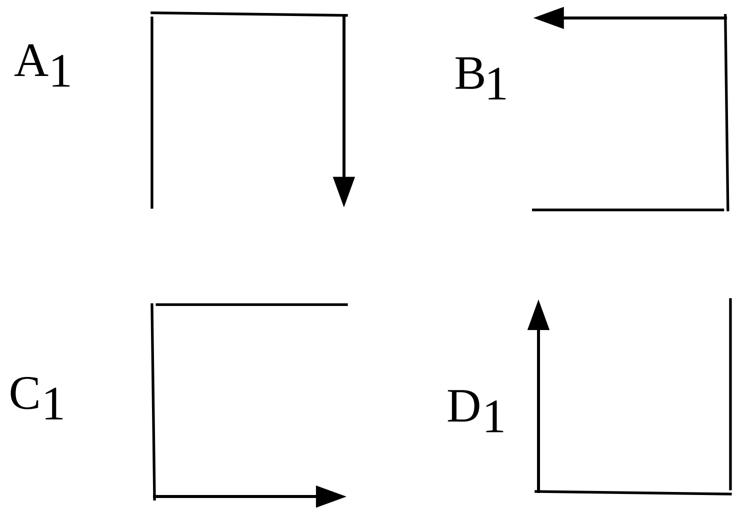
(see figure)

Hilbert Curves

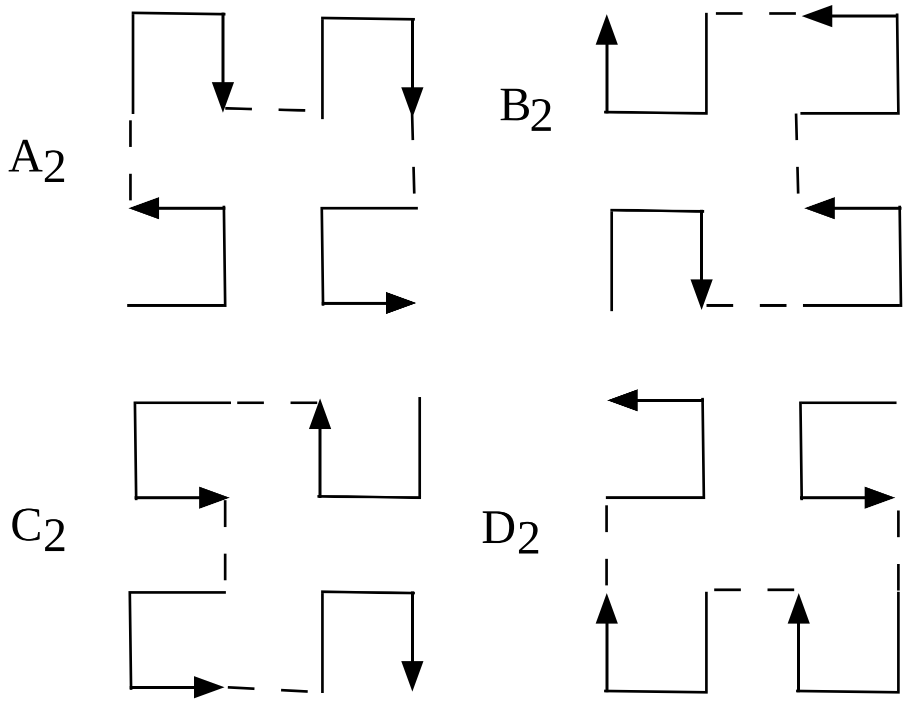
Space filling curves

As order goes to infinity,
every point in the area is passed through

Four basic primitives:

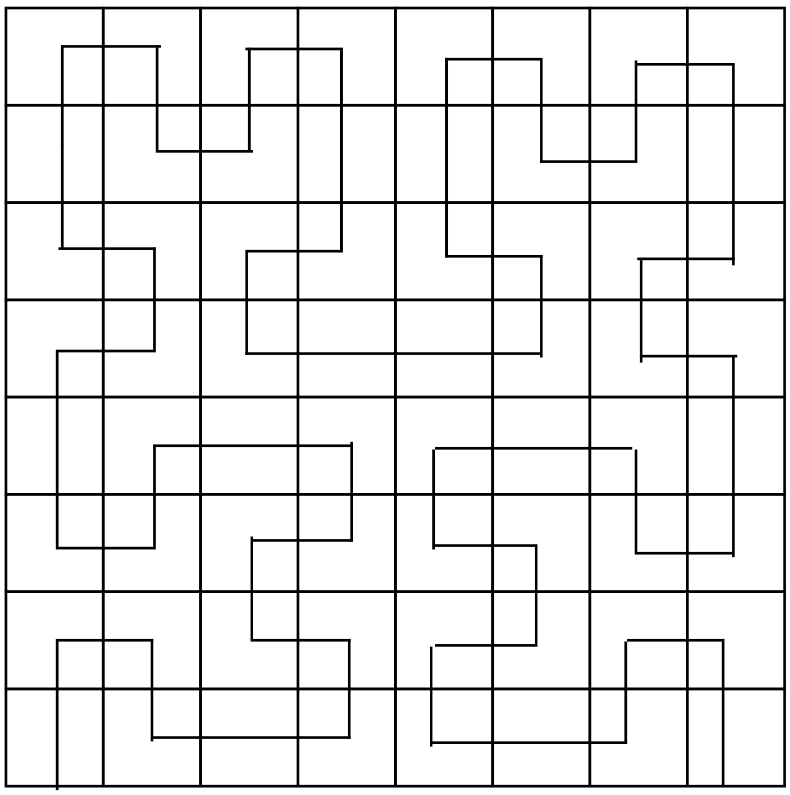


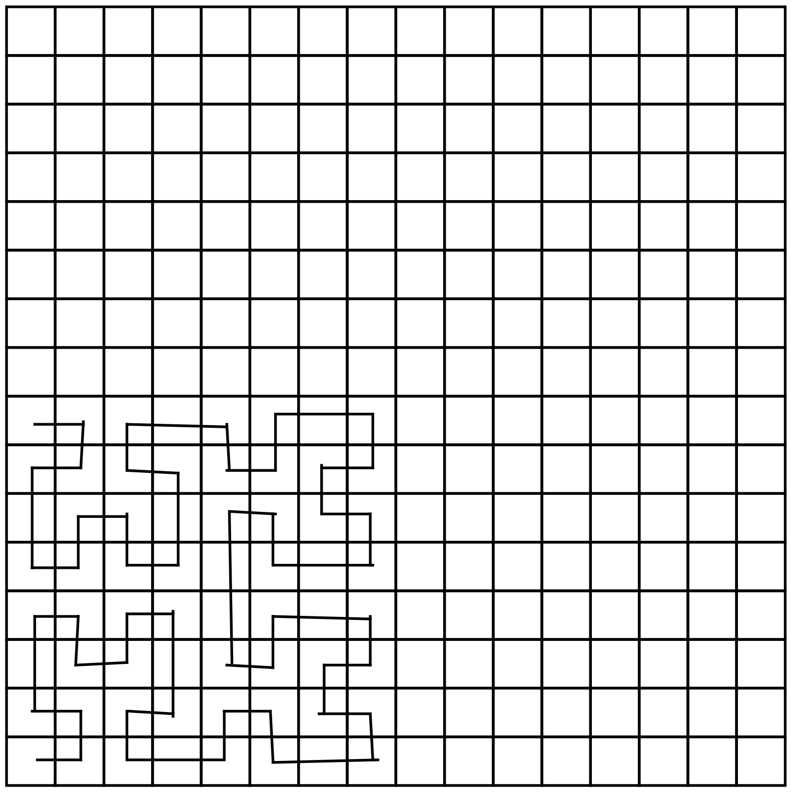
Connected by extra lines as follows:



Hilbert's Curve Rules:

A_{i+1} = B_i up A_i right A_i down C_i
B_{i+1} = A_i right B_i up B_i left D_i
C_{i+1} = D_i left C_i down C_i right A_i
D_{i+1} = C_i down D_i left D_i up B_i





Curve never crosses itself
Curve is arbitrarily close to any point in square
Length of curve is infinite
L_{i+1} versus L_i?

Strictly self-similar curves:

- Koch
- Peano, etc

Statistically self similar

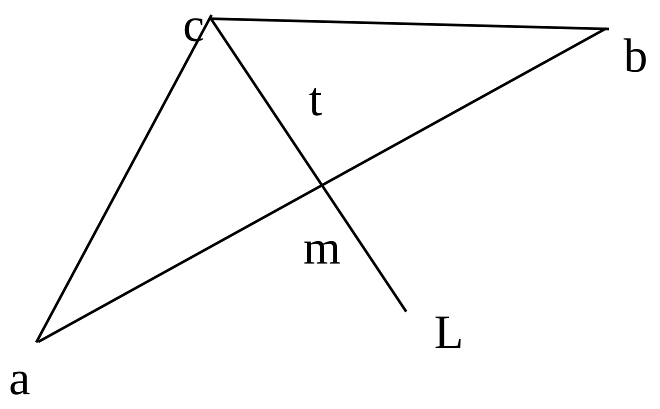
- Fern
- Coastline
  - Mapmaker puts in bays, peninsulas, fiords
    - Accurate? No! eg Cape Cod
    - If look at coastline at different scales
      - get similar pattern of wiggles and bays
    - What is the length of the coastline?
      - I step it off
      - My cat steps it off
      - An ant steps it off
      - eg measure it with dividers set at different lengths
      - length depends on scale at which it is measured
      - Coastline fractal dimensions about 1.15 to 1.25
- Other examples
  - clusters of stars
  - shapes of snowflakes

How to program statistically self-similar fractals

Random Midpoint Displacement Algorithm

For each line segment in object,

Replace it by an "elbow" with random offset



Line is ab
L is it's bisector
m is it's midpoint

choose t randomly

$c = (m_x - (b_y - a_y)\,t,\ \ m_y + (b_x - a_x)\,t\,)$

For each segment choose a new random value of t

Use normal (Gaussian) distribution with mean of 0

Standard deviation of s

Recursively apply such an algorithm

At each recursive level can change s by multiplying it by a factor f

f = 1 gives Brownian motion

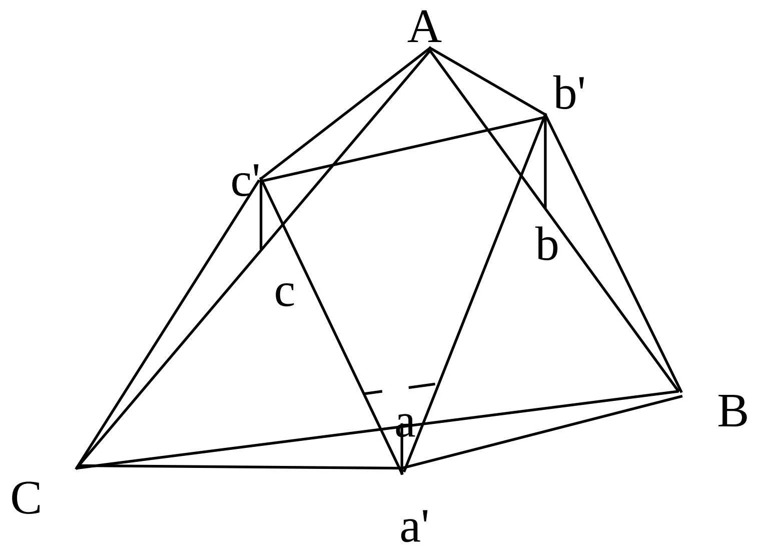
f < 1 gives "smooth" curve

f > 1 gives very rough surface

Could easily model a coastline using midpoint displacement

Similar algorithm for fractal surfaces

Use to build artificial landscapes, mountains, etc



Represent surfaces by a triangular mesh
At each level of recursive algorithm
Find midpoint of each side of triangle (a,b and c)
Add random value to each midpoint (get a', b' and c')
Form four new triangles: Ca'c', Ba'c', Ab' c', a'b'c'