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15-826: Multimedia Databases and Data Mining

Lecture #24: Compression - JPEG, MPEG, fractal

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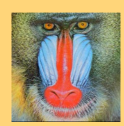
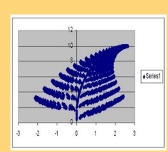
Problem



- Q1: How to compress images?
  – A1:
- Q2: How to compress video?
  – A2:
- Q3: How to compress FRACTAL images?
  – A3:



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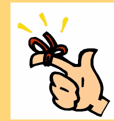
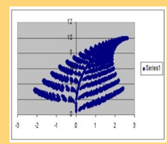


Solutions

- Q1: How to compress images?
  - A1: DCT (jpeg)
- Q2: How to compress video?
  - A2: mpeg
- Q3: How to compress FRACTAL images?
  - A3: IFS (Iterated function systems)



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Must-read Material

- JPEG: Gregory K. Wallace, *The JPEG Still Picture Compression Standard*, CACM, 34, 4, April 1991, pp. 31-44
- MPEG: D. Le Gall, *MPEG: a Video Compression Standard for Multimedia Applications* CACM, 34, 4, April 1991, pp. 46-58
- Fractal compression: M.F. Barnsley and A.D. Sloan, *A Better Way to Compress Images*, BYTE, Jan. 1988, pp. 215-223.

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Outline

Goal: 'Find similar / interesting things'

- Intro to DB
- ➡ Indexing - similarity search
- Data Mining

Indexing - Detailed outline

- primary key indexing
- ..
- multimedia
- Digital Signal Processing (DSP) tools
- ➡ Image + video compression
  - JPEG
  - MPEG
  - Fractal compression

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Motivation

- Q: Why study (image/video) compression?

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Motivation

- Q: Why study (image/video) compression?
- A1: feature extraction, for multimedia data mining
- A2: (lossy) compression = data mining!

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JPEG - specs

- (Wallace, CACM April '91)
- Goal: universal method, to compress
  - losslessly / lossily
  - grayscale / color (= multi-channer)
- What would you suggest?

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JPEG - grayscale - outline

- step 1) 8x8 blocks (why?)
- step 2) (Fast) DCT (why DCT?)
- step 3) Quantize (fewer bits, lower accuracy) ← loss
- step 4) encoding
  - DC: delta from neighbors
  - AC: in a zig-zag fashion, + Huffman encoding

Result: 0.75-1.5 bits per pixel (8:1 compression) - sufficient quality for most apps

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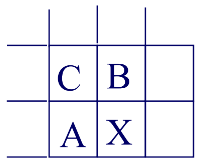
DETAILS

JPEG - grayscale - lossless

- Predictive coding:



X= *f* (A, B, C)
eg. X= (A+B)/2, or?

- Then, encode prediction errors

Result: typically, 2:1 compression

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DETAILS

JPEG - color/multi-channel

- apps?
- image components = color bands = spectral bands = channels
- components are interleaved (why?)

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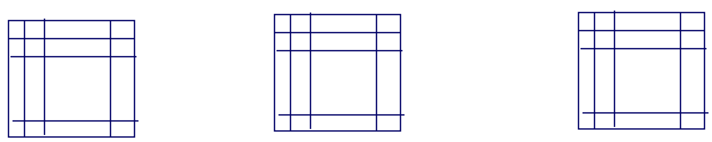
DETAILS

JPEG - color/multi-channel

- apps?
- image components = color bands = spectral bands = channels
- components are interleaved (why?)
  – to pipeline decompression with display



8x8 'red' block 8x8 'green' block 8x8 'blue' block

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DETAILS

JPEG - color/multi-channel

- tricky issues, if the sampling rates differ
- Also, hierarchical mode of operation: pyramidal structure
  – sub-sample by 2
  – interpolate
  – compress the diff. from the predictions

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JPEG - conclusions

- grayscale, lossy: 8x8 blocks; DCT; quantization and encoding
- grayscale, lossless: predictions
- color (lossy/lossless): interleave bands

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Indexing - Detailed outline

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- Digital Signal Processing (DSP) tools
- Image + video compression
  - JPEG
  - MPEG
  - Fractal compression

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MPEG

- (LeGall, CACM April '91)
- Video: many, still images
- Q: why not JPEG on each of them?

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MPEG

- (LeGall, CACM April '91)
- Video: many, still images
- Q: why not JPEG on each of them?

- A: too similar - we can do better! (~3-fold)

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DETAILS

MPEG - specs

- ??

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DETAILS

MPEG - specs

- acceptable quality
- asymmetric/symmetric apps (#compressions vs #decompressions)
- Random access (FF, reverse)
- audio + visual sync
- error tolerance
- variable delay / quality
- editability

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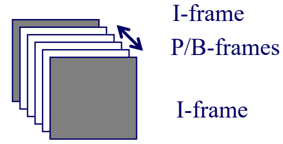
DETAILS

MPEG - approach

- main idea: balance between inter-frame compression and random access
- thus: compress *some* frames with JPEG (*I-frames)*
  - rest: prediction from motion, and interpolation
  - P-frames (predicted pictures, from I- or P-frames)
  - B-frames (interpolated pictures - never used as reference)



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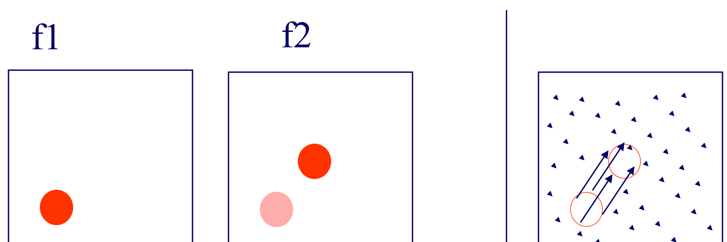
MPEG - approach

- useful concept: '*motion field*'



Lukas – Kanade algorithm:
Bruce D. Lucas (1984) *Generalized Image Matching by the Method of Differences* (doctoral dissertation, RI, CMU)

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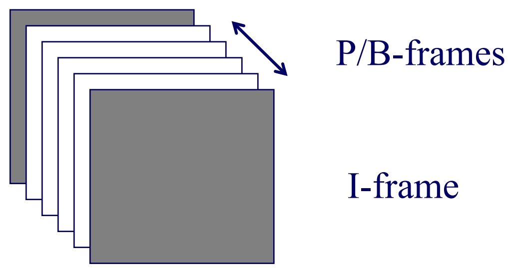
MPEG - conclusions

- with the I-frames, we have a balance between
  - compression and
  - random access



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Indexing - Detailed outline

- primary key indexing
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- Digital Signal Processing (DSP) tools
- Image + video compression
  - JPEG
  - MPEG
  - Fractal compression

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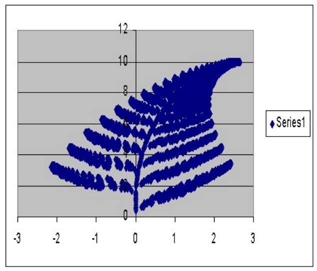
Fractal compression

- 'Iterated Function systems' (IFS)
- (Barnsley and Sloane, BYTE Jan. 88)
- Idea: real objects may be self-similar, eg., fern leaf



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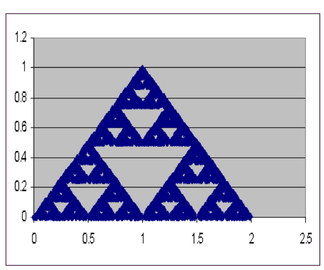
Fractal compression

- simpler example: Sierpinski triangle.
  - has details at every scale -> DFT/DCT: not good
  - but is easy to describe (in English)
- There should be a way to compress it very well!
- Q: How??



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Fractal compression

- simpler example: Sierpinski triangle.
  - has details at every scale -> DFT/DCT: not good
  - but is easy to describe (in English)
- There should be a way to compress it very well!
- Q: How??
- A: several, affine transformations
- Q: how many coeff. we need for a (2-d) affine transformation?

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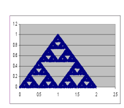
Fractal compression

- A: 6 (4 for the rotation/scaling matrix, 2 for the translation)
- (x,y) -> w((x,y))= (x' , y')
  - x' = a x + b y + e
  - y' = c x + d y + f
- for the Sierpinski triangle: 3 such transformations - which ones?



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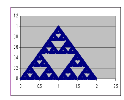
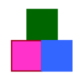
Fractal compression

- A: prob (~ fraction of ink)

	a	b	c	d	e	f	p
w1	0.5	0	0	0.5	0	0	1/3
w2	0.5	0	0	0.5	1	0	1/3
w3	0.5	0	0	0.5	0.5	0.5	1/3





Fractal compression

- The above transformations 'describe' the Sierpinski triangle - is it the only one?
- ie., how to de-compress?

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Fractal compression

- The above transformations ‘describe’ the Sierpinski triangle - is it the only one?
- A: YES!!!
- ie., how to de-compress?
- A1: Iterated functions (expensive)
- A2: Randomized (surprisingly, it works!)

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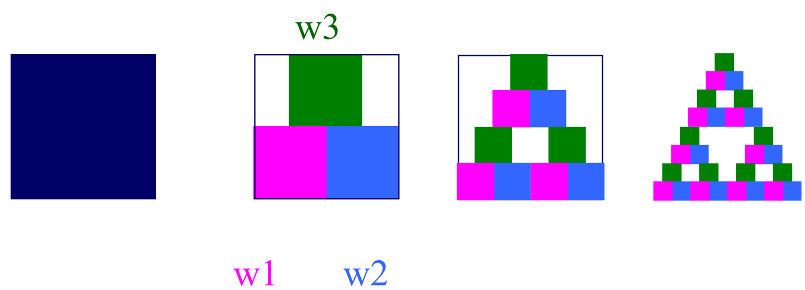
Fractal compression

- Sierpinski triangle: is the ONLY fixed point of the above 3 transformations:



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Fractal compression

- We' ll get the Sierpinski triangle, NO MATTER what image we start from! (as long as it has at least one black pixel!)
- thus, (one, slow) decompression algorithm:
  - start from a random image
  - apply the given transformations
  - union them and
  - repeat recursively
- drawback?

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Fractal compression

- A: Exponential explosion: with 3 transformations, we need 3***k* sub-images, after *k* steps
- Q: what to do?

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Fractal compression

- A: PROBABILISTIC algorithm:
  - pick a random point (x0, y0)
  - choose one of the 3 transformations with prob. p1/p2/p3
  - generate point (x1, y1)
  - repeat
  - [ignore the first 30-50 points - why??]
- Q: why on earth does this work?
- A: the point (x_n, y_n) gets closer and closer to Sierpinski points (n=1, 2, ...), ie:

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Fractal compression

... points outside the Sierpinski triangle have no chance of attracting our 'random' point (x_n, y_n)

Q: how to compress a real (b/w) image?

A: 'Collage' theorem (informally: find portions of the image that are miniature versions, and that cover it completely)

Drills:

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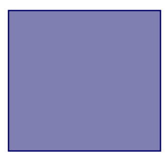
Fractal compression

Drill#1: compress the unit square - which transformations?



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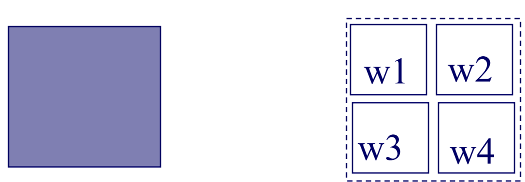
Fractal compression

Drill#1: compress the unit square - which transformations?



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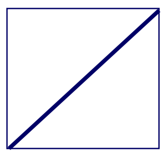
Fractal compression

Drill#2: compress the diagonal line:



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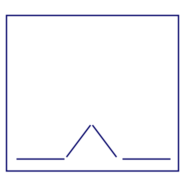
Fractal compression

Drill#3: compress the 'Koch snowflake':



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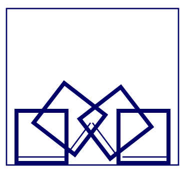
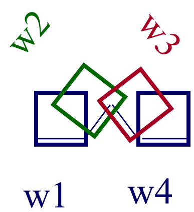
Fractal compression

Drill#3: compress the 'Koch snowflake': (we can rotate, too!)





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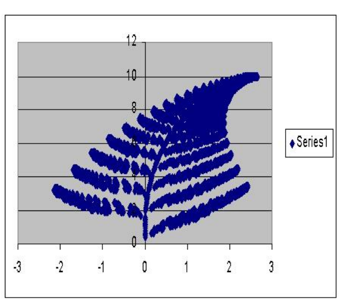
Fractal compression

Drill#4: compress the fern leaf:



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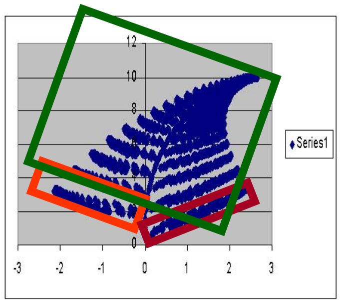
Fractal compression

Drill#4: compress the fern leaf: (rotation + diff. p_i)



PS: actually, we need one more transf., for the stem

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Fractal compression

- How to find self-similar pieces automatically?
- A: [Peitgen+]: eg., quad-tree-like decomposition

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Fractal compression

- Observations
  - may be lossy (although we can store deltas)
  - can be used for color images, too
  - can ‘focus’ or ‘enlarge’ a given region, without JPEG’s ‘blockiness’

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Also, for generation

- Q: How to generate 80-20 (80-50) traffic?

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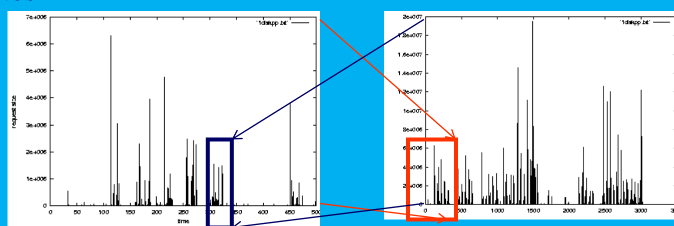
Solution #3: traffic

- disk traces: self-similar:

#bytes



time

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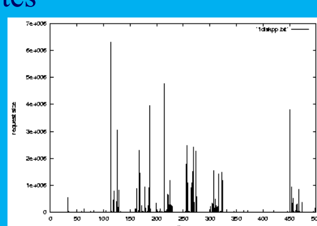
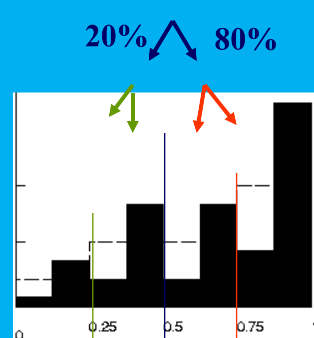
Solution #3: traffic

- disk traces (80-20 ‘law’ = ‘multifractal’)

#bytes



time



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Also, for generation

- Q: How to generate 80-20 (80-50) traffic?
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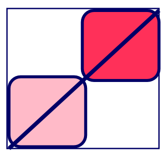

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Also, for generation

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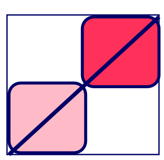

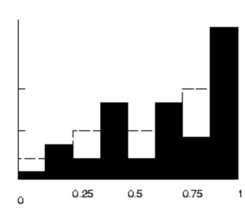

W1: shrink by ½; weight 20%
W2: shrink by ½; shift by ½; weight 80%

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Also, for generation

- Q: How to generate realistic 2-d/*n*-d clouds of points (say, like cities of the US, or stars in the sky)?
- A: similarly:
  - find w_1, ... w_n
  - to match desirable fractal dimension

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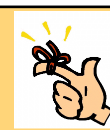
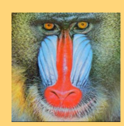


Solutions



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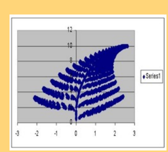
  - A1: DCT (jpeg)
- Q2: How to compress video?
  - A2: mpeg (i-frames; interpolation)
- Q3: How to compress FRACTAL images?
  - A3: IFS (Iterated function systems)



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Resources/ References

- IFS code: www.cs.cmu.edu/~christos/SRC/ifs.tar
- Gregory K. Wallace, *The JPEG Still Picture Compression Standard*, CACM, 34, 4, April 1991, pp. 31-44

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References

- D. Le Gall, *MPEG: a Video Compression Standard for Multimedia Applications* CACM, 34, 4, April 1991, pp. 46-58
- M.F. Barnsley and A.D. Sloan, *A Better Way to Compress Images*, BYTE, Jan. 1988, pp. 215-223
- Heinz-Otto Peitgen, Hartmut Juergens, Dietmar Saupe: *Chaos and Fractals: New Frontiers of Science*, Springer-Verlag, 1992