Signals, Images, ... What's Next in Scientific Visualization

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"A picture is worth a thousand words"

- scientists use this principle to convey information about scientific concepts, data, and models
- cheap computers and data acquisition tools means enormous amounts of data
- how do we interpret it all?
- enter the methods of Signal Analysis / Scientific Visualization / Imaging Science

Agenda

- my point of view
- two themes of Imaging Science - Scientific Visualization / Signal analysis
- examples of signal, images, ...
- examples of visualization concepts and methods
- implications for mathematics, science and engineering education

Background for my view point

- a denizen of the mathematics department at Rose-Hulman, a small, undergraduate institute of technology
- RHIT has degrees in various branches of engineering, biology, chemistry, physics, computer science, and mathematics
- interdisciplinary certificate program in imaging systems
  - Applied Optics and Physics
  - Electrical Engineering
  - Computer Science
  - Mathematics

Two themes of Imaging Science-1

- analysis & processing
  - data representing a physical situation is analyzed or transformed to improve scientific understanding, control a process, improve data quality, e.g., acoustical analysis, remote sensing, medical diagnosis
- synthesis & creation
  - information is created in the form of sound and images, e.g., electronic music and speech, virtual reality, “Toy Story”

Two themes -2

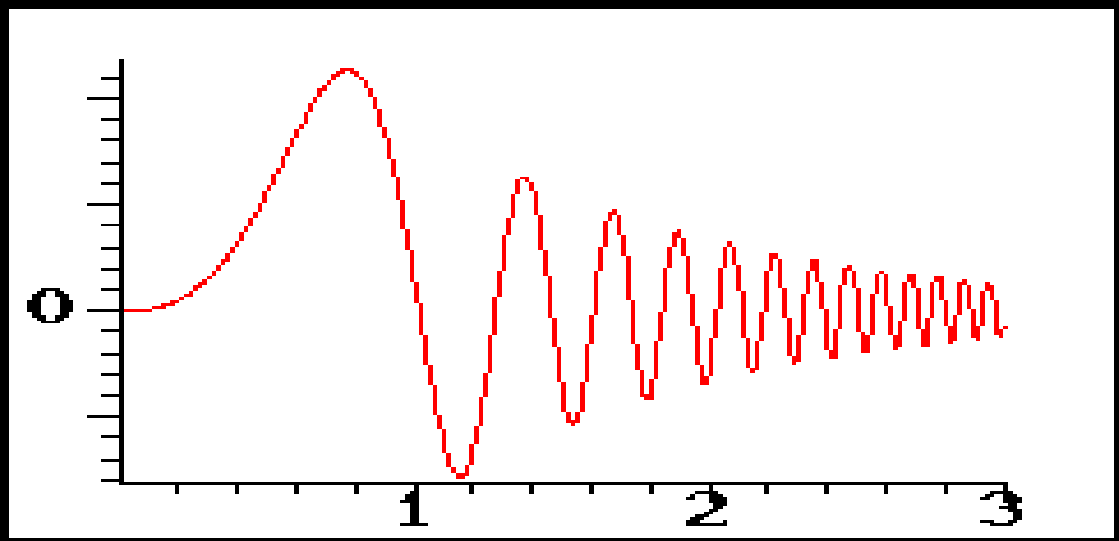
- methods frequently are the same
- the motivations are different and inverse to each other
  - analyze data which comes from a given situation
  - synthesize data to produce a given situation
- we give examples of both perspectives in our discussion

Mathematical perspective signals & signal dimensionality

- a “signal” is one or measurements of one or more physical quantities distributed over time and/or space
- most signals are 1D, 2D or 3D

Examples of signals -1

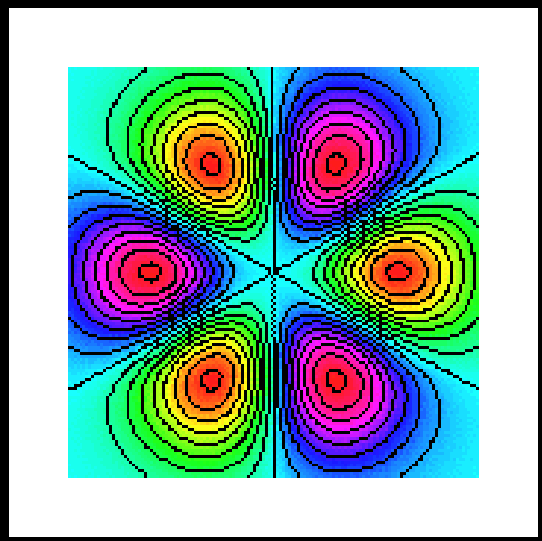
- 1D signals -
  - graph of a measurement over time



  - audio

Examples of signals -2

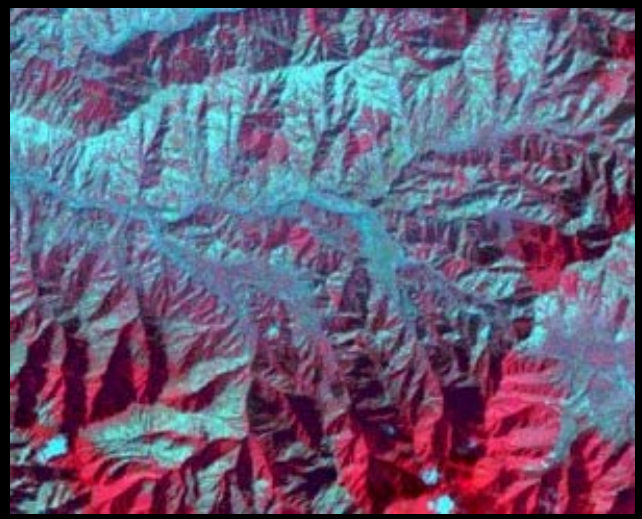
- 2D signal examples
  - image and contour representation

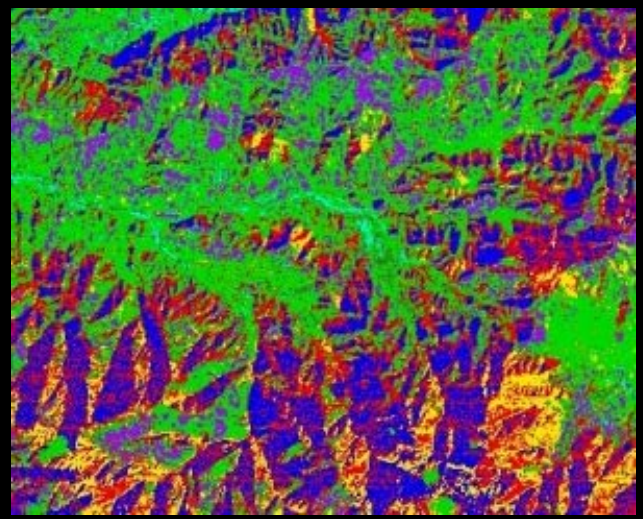


  - (maple show - SigmaXipics.mws)

Examples of signals -3

- 2D signal examples
  - real scientific "images" (from Professor Millette's website)



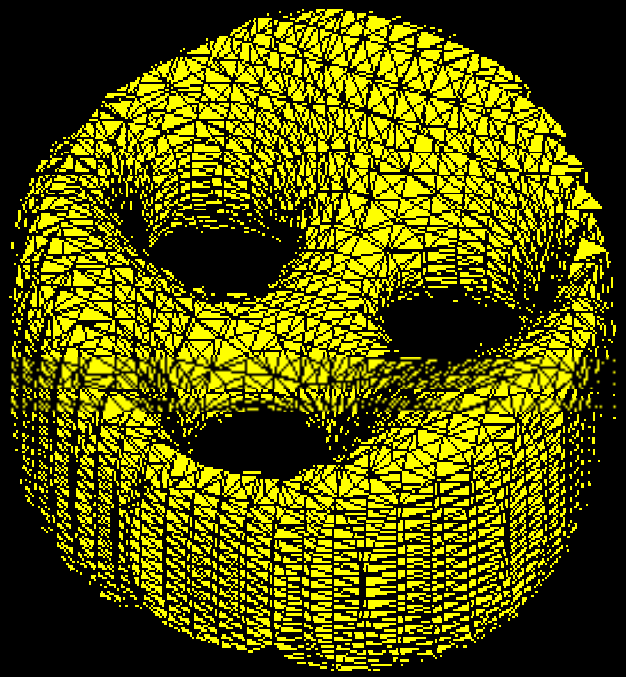


Examples of signals -4

- 3D signals
  - movies - dimensions: two spatial, one time
  - medical 3D imaging - CAT scan, MRI
    X-rays are more 2D-like

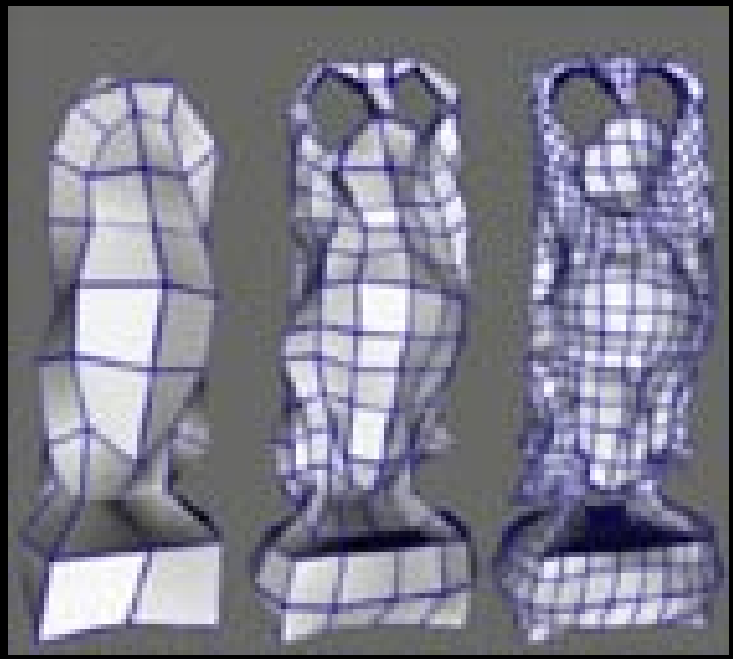
Examples of signals -5

- 3D signals
  - objects in space



Examples of signals -6

- 3D signals
  - objects in space (from Caltech geometric modeling website)



Methods and examples of signal and image analysis

1. Fourier based analysis and synthesis
   - smoothing data, compression ideas
2. image feature analysis via vector quantization
3. multi-resolution analysis in fingerprint compression
4. 3D image feature analysis in medical diagnostics (discussion only, no pictures)
5. 3D - geometric modeling

Example 1
Fourier based analysis

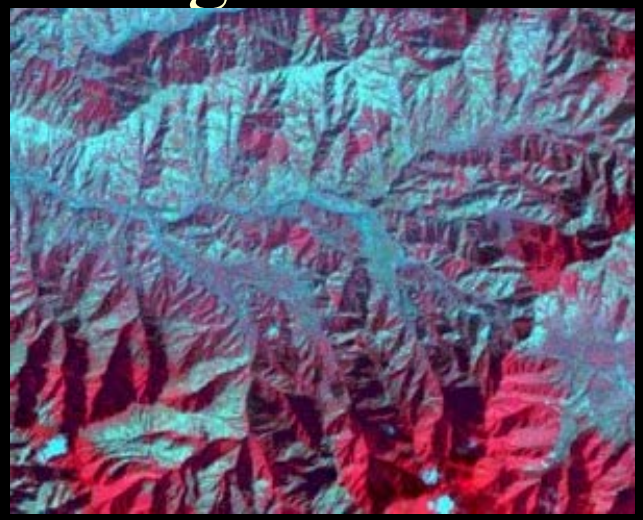
- Fourier analysis: decompose signal into sine and cosine waves
- example of decomposition - find frequencies (Matlab show: analsyndctsx.m)
- application of analysis noise removal (dctsmoothdemo2.m)
- we also get the idea for data compression

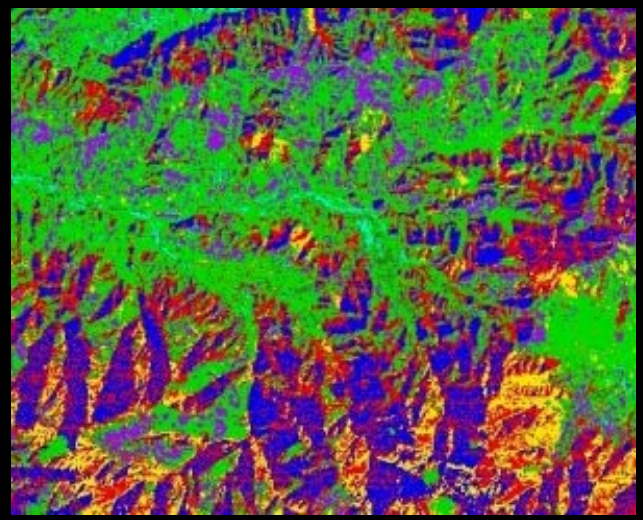
Example 2 - vector quantization and feature analysis -1

- show Matlab demo darhist.m
- examples show idea of multi-dimensional "correlation" histograms
- colour is a natural 3D histogram analysis

Example 2 - vector quantization and feature analysis -2

- images and can show three way correlation among variables





Example 2 - vector quantization and feature analysis -3

- vector quantization can be used extract features with correlated characteristics
- show darvect.m

Example 3 -wavelet analysis for fingerprint compression

- wavelet analysis is also called (dyadic) multi-resolution analysis
- wavelet dyadic resolution demo
  - dwt2stagesnorm.m
- why compression works
  - dwt2stagesunnorm.m

Example 4 medical diagnostics

- multi-resolution analysis can be use to detect small abnormalities in mammograms (checking up on a radiologists work)
- Using MRI imaging the exterior surface of the colon can be imaged. Challenge find an algorithm to find polyps (bumps)

Example 5 geometric modeling

- interesting examples of geometric modeling are on the Caltech website specifically
  - http://www.multires.caltech.edu/software/pgc/
  - in pubs.htm
  - and the paper compression.pdf

Implications for science, math, and engineering Education-1

- use visualization for conceptual understanding in basic science and math, especially calculus, using computer based tools
- need to be facile with computing as a learning and research tool
- initially concentrate on concept and utilizing tools rather than developing them

Implications for science, math, and engineering education-2

- excellent educational opportunities in computer science, mathematics, electrical engineering and other sciences
- the background math for understanding is not all calculus based
- discrete digital analysis is simpler to implement on the computer than calculus based continuous analysis

Thank you and a URL

- Thanks for coming
- Thanks for inviting me
- Any questions???
- http://www.rose-hulman.edu/~brought/Epubs/sigmaxi/sciviz.html