Signal Processing
For
Image Processing

- Images
  - Collection of photons
  - Human eye has little surface area
  - Telescopes collect photons from a larger area
  - Film cameras collect photons over time
  - Digital camera images need to be integrated to collect more photons
- Signals
  - A dimensioned sequence
  - X or independent axis
    - Time
    - Space
  - Y or dependent axis
    - Color amplitude – red, green, blue
    - Intensity – some combination of inputs
  - Data sets
    - Create new ones
      - Equations
      - Files or clipboard
      - Draw new ones with graph editor
    - Use saved signals
      - Files
      - Clipboard saves of other panels
      - Clipboard saves of image cross-sections
- Operations
  - Inputs, transfer functions, outputs – basis of all signals and systems analysis

    $Y(t) = X(t) \Theta H(t)$

    Where X(t) is an input, H(t) is a transfer function, Θ is an operation, Y(t) is the output

  - Unary operations
    - Delete
    - Derivative
    - Integrate
    - Flip axis
    - Floor/Ceiling
    - Fourier transform – uses Cooley-Tukey Fast Fourier Transform algorithm
      - Pads to length of ^2

- Shows both real and imaginary parts (imaginary is green)
- Completely reversible by multiple transformations
  - $F(\omega) = \int f(t) * e^{-i\omega t}\, dt$
  - f(t) ⇔ $F(\omega)$
  - $F(-\omega)$ ⇔ f(t)
  - f(t) ⇔ $F(\omega)$ requires 3 FFT transformations to cancel -1

- Invert
- Resample
- Shift
- Trim
- Zero

- Binary operations

  - Add
  - Append
  - Convolution
    - $y(t) = \int x(\tau) * h(t-\tau)\, d\tau$
  - Correlation
    - y(t) $= \int x(\tau) * h(t+\tau)\, d\tau$
  - Multiply

- Functions that convolve in the time domain multiply in the frequency domain and vice-versa

- Potentially useful utilities
  - Adjustable filter -- build a controller of a real-life problem describable by differential equations
  - Calculate the transfer function knowing the input and output

Image Processing

- Images
- Shaping the views
  - Centering for primary highlight (feature) discovery
  - Center and edge avoidance for secondary highlight discovery
- High-level operations
  - Averaging
  - Integration
  - Correlation
    - FFT

- y(t) = $\int_0^\infty h(\tau) \cdot x(t-\tau) d\tau$ – convolution, can use FFT
- y(t) = $\int_0^\infty h(\tau) \cdot x(t+\tau) d\tau$ – correlation, can use FFT with x(t) flipped

  - Recursive to lowest pixel level
    - Smaller FFT operations
    - Faster FFT operations

- Signals from images
  - Edge and corner detection
    - Laplacian and difference operators
    - Two dimensional operations
    - Kernels allow area operations
      - Derive Laplacian
      - Extend Laplacian to difference operator
  - Arbitrary cross-sections
  - Horizontal and vertical highlights
  - Rotational highlight
- RGB operations
  - Offset
  - Gain
  - Joined or unjoined RGB controls
  - Best used with arbitrary hand-drawn cross-section
- Two-dimensional operations
  - Image transforms
    - Average
    - Decimate
    - Derivative
    - Dilate
    - Erode
    - Laplacian -- $\nabla^2 \Phi = \nabla(\nabla \cdot \Phi)$
      - Positive
      - Negative
      - Expanded and unexpanded to display scale
    - Limit
    - Difference
    - Maximum
    - Mean
    - Minimum
    - Variance
- Image movement
  - X or Y translation
  - Rotation
  - Magnification

        - Resampling
        - Drag to area of interest
        - Operates on image pixels, not rendered pixels
- User-selectable algorithms
    - Black image subtraction
    - User-modifiable processing algorithms
        - Algorithm editor
            - Can be run immediately
            - Can be run during image combination processing
- Alignment algorithm selection
    - Shift before rotate
    - Rotate before shift
    - Linear regression – work in-progress
- Filter
    - Hand-drawn
    - Copy from Signal Analyzer program
    - Sharpening, edge focusing – CT operation
- Debug displays
- The process
    - Decimate to ~512 pixels
    - Mean
    - Do not expand derivative or difference operator to scale
    - Difference or Laplacian
    - Calculate undesired noise level – show M33_Offsets 1,2,3 at default and limit=75
    - Limit noise
    - Dilate
    - Erode
    - Find features or highlights– X, Y, rotations
    - Match features via correlations
    - Move image to match
    - Integrate or average
    - Repeat for each additional image