HEAd '20

Self-Contained Jupyter Notebook Labs Promote Scalable Signal Processing Education

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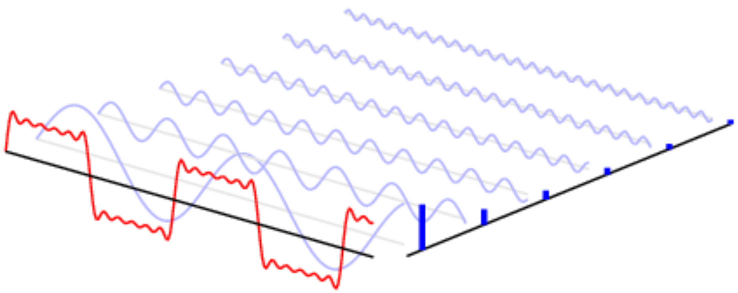
Where Our Course is Situated

Python programming
Complex numbers
Calculus
Linear algebra

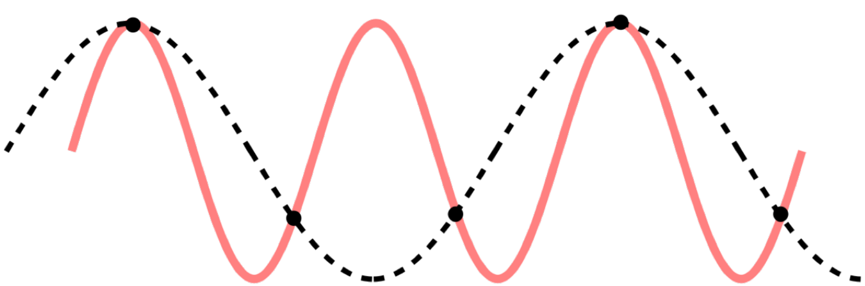
LTI systems
Fourier analysis
A-to-D sampling
Z and Laplace Transforms

Signals & Systems

Fourier Analysis & Decomposition

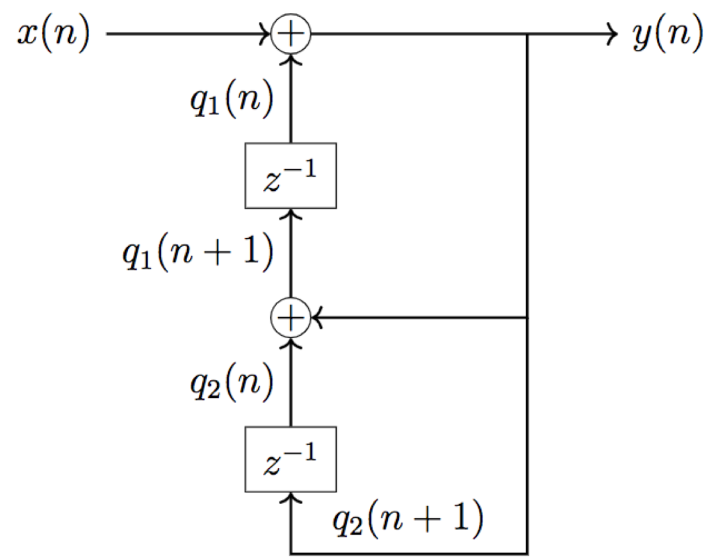


Sampling Theory



Systems: Fibonacci Seq. Generator

$$y(n) = y(n-1) + y(n-2) + x(n)$$



$$x(n) = 1, 0, 0, 0, 0, 0, \ldots$$
$$y(n) = 1, 1, 2, 3, 5, 8, \ldots$$

The Need for Labs

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-i\omega t} dt$$

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(\omega) e^{i\omega t} d\omega$$

"When will I ever use this in the *real* world?"

Scalable Signals & Systems Labs

Want:

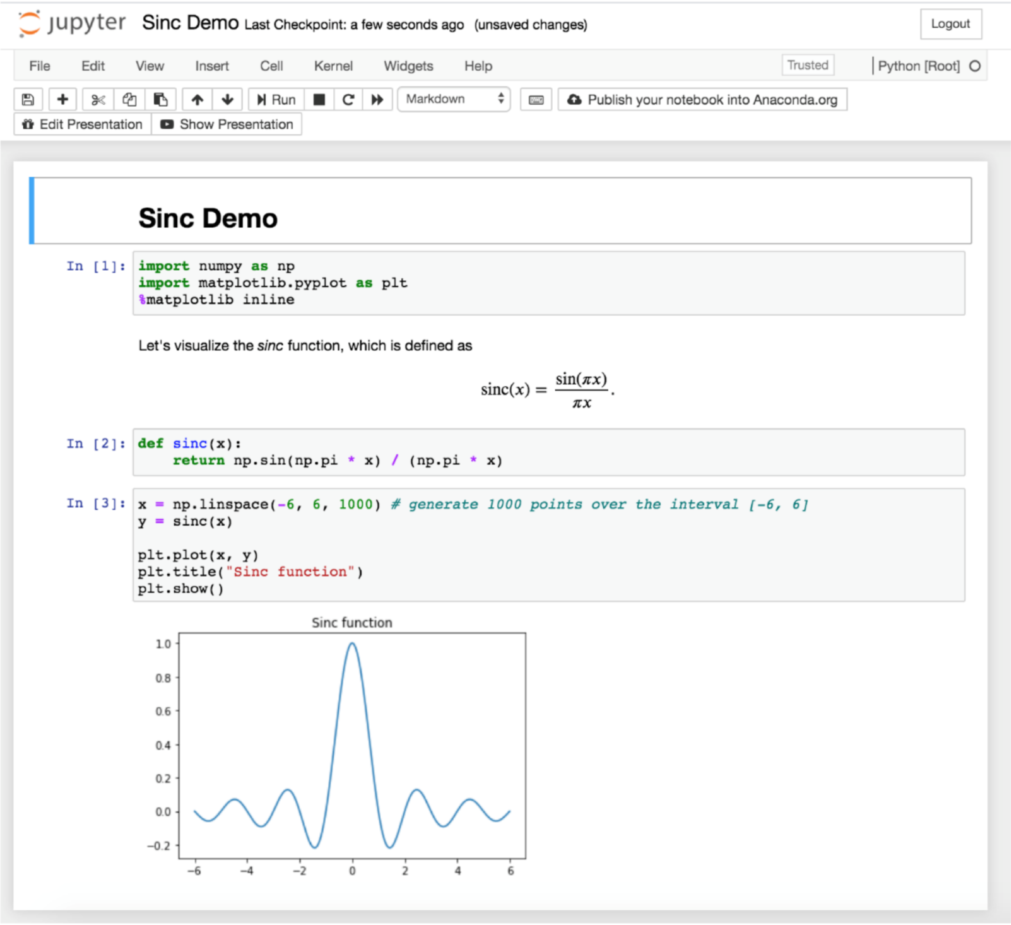
- Applications-driven
- Teach computational skills
- Self-contained

Avoid:

- Need for physical space
- Hardware
- In-person checkoffs

The Jupyter Notebook

- Interactive interface
  - Create and run code cells
  - Seamless integration with plotting/visualization tools
- Runs in browser
- Supports Julia, Python, R, and many other programming languages



The Jupyter Notebook

```
Mathematically, we represent a note with frequency $f$ as a sine wave at
that frequency with some amplitude $A$ and phase $\phi$,

$$A \sin(2\pi f t + \phi),$$

where $A$ would be determined by how hard the note on the piano is
physically pressed, for instance, and the phase $\phi$ corresponding to a
temporal offset is typically just taken to be zero.
```

↓

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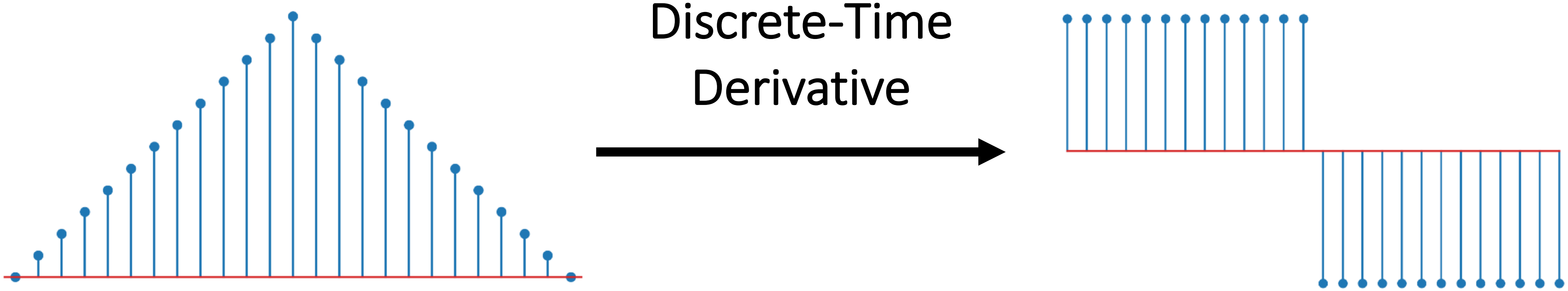
Applications-Driven Labs



Finite-Difference Filter for Numerical Differentiation

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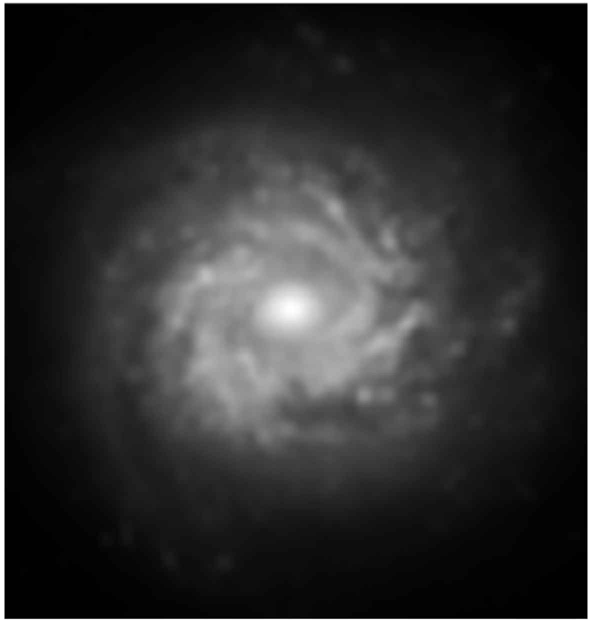
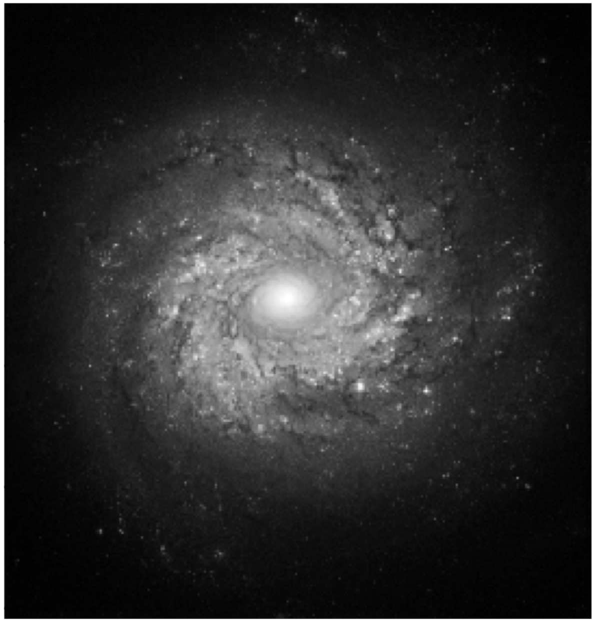
Applications-Driven Labs



Deconvolution



Deblur Hubble Space Telescope Image

Teach Computational Skills

```
In [46]: lab1_helper.get_speedup(np.convolve, numpyless_conv)

Without NumPy: 0.5981 sec
With NumPy:    0.0001 sec
NumPy gives a 6334.9323x speedup
```

Use Python libraries to accelerate computation 6,000x

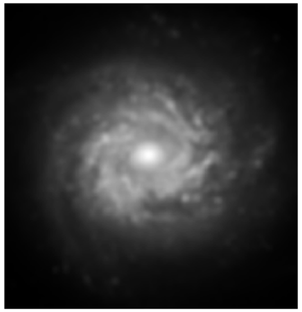
Teach Computational Skills

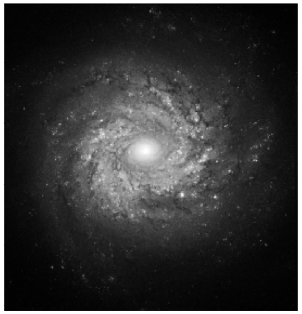
```
(Current Best) RMSE: 12.303, Sigma: 0.204, Kernel Size: 1
```

```
(Current Best) RMSE: 1.962, Sigma: 5.102, Kernel Size: 15

Original RMSE: 12.303
Best RMSE:     1.962
Parametric sweep gives a 6.27x better result.
```

Blurry

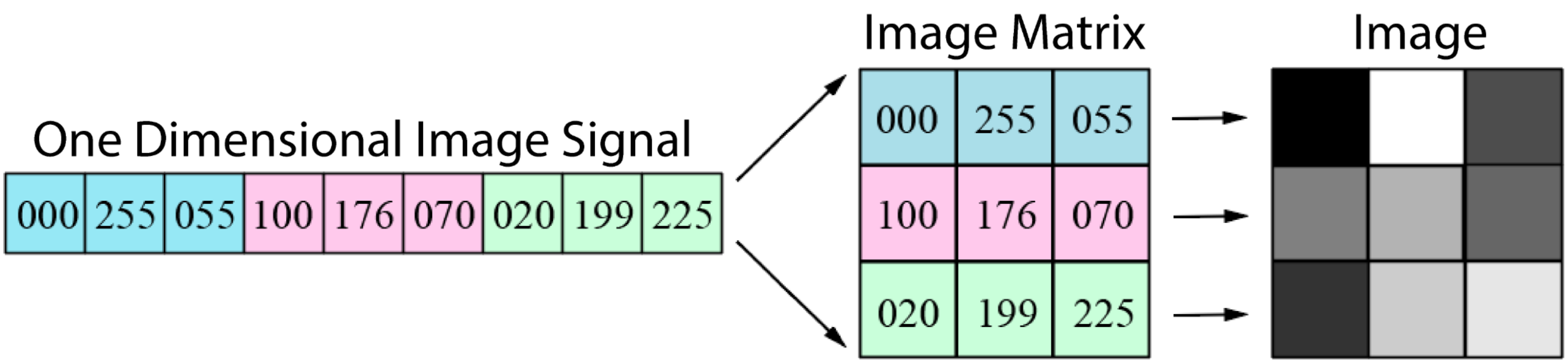




Deblurred

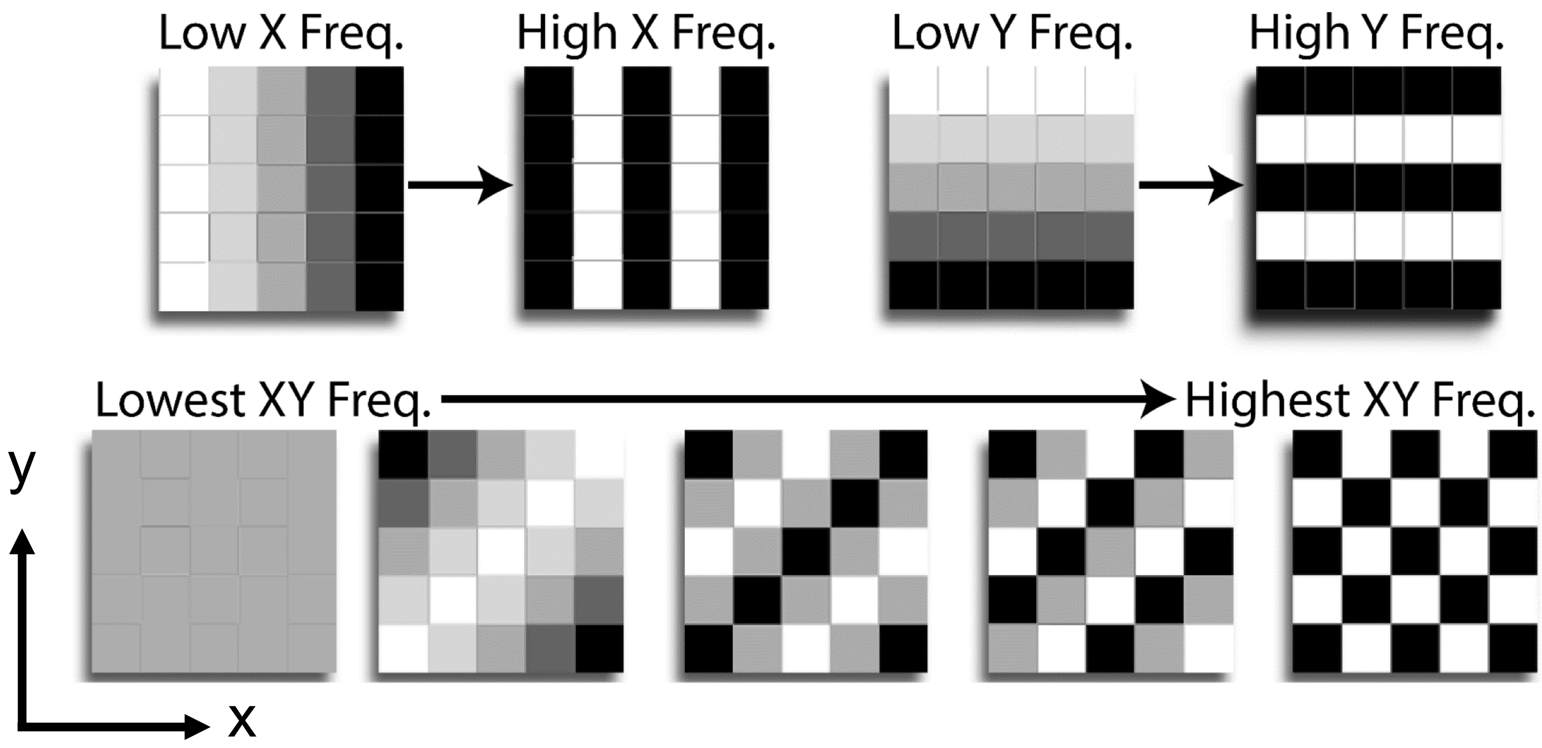
Use a parametric sweep for numerical optimization

Self-Contained Labs



Generalize 1D signals to 2D signals

Self-Contained Labs



Generalize 1D frequencies to 2D frequencies

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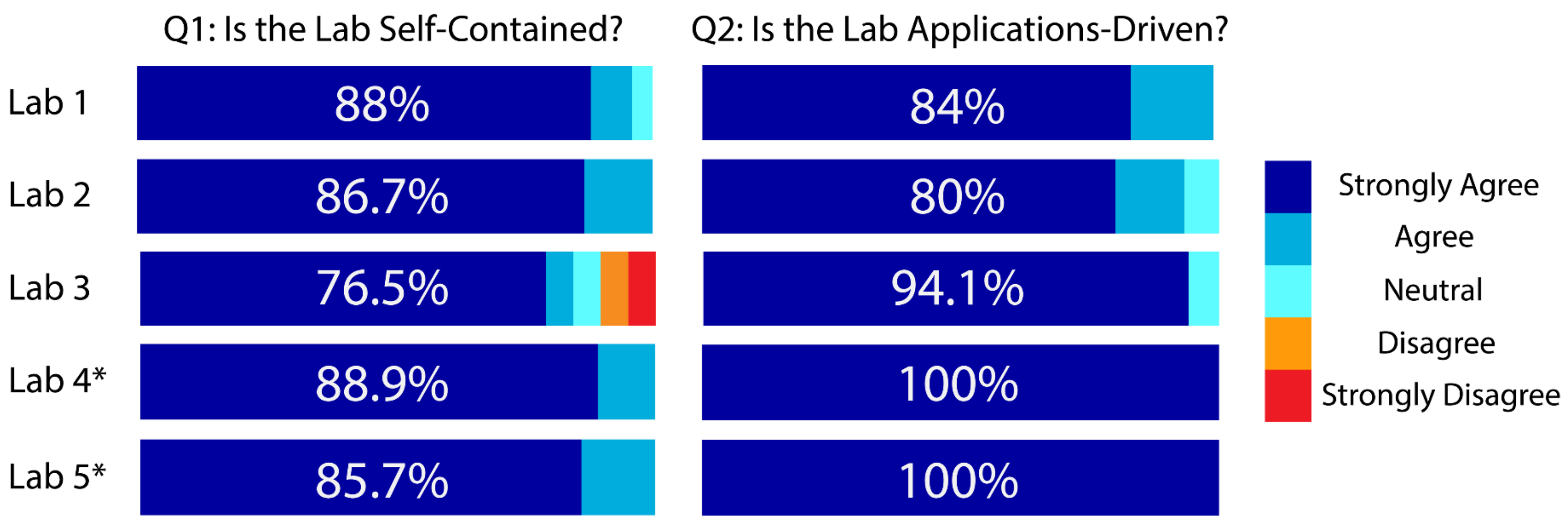
Student Feedback



*lower response rate due to COVID-19

Spring 2020 student feedback