



Self-Contained Jupyter Notebook Labs Promote Scalable Signal Processing Education

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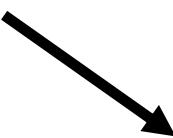


Where Our Course is Situated

Python programming

Complex numbers

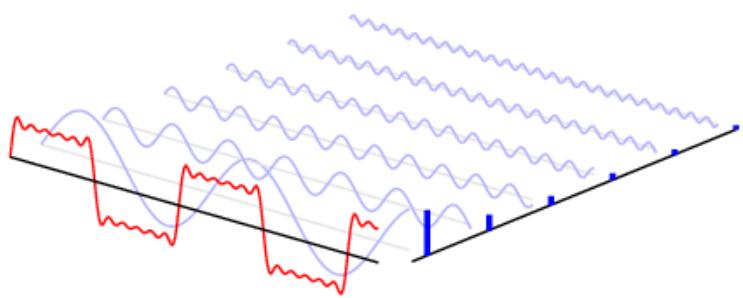
Linear algebra
Calculus



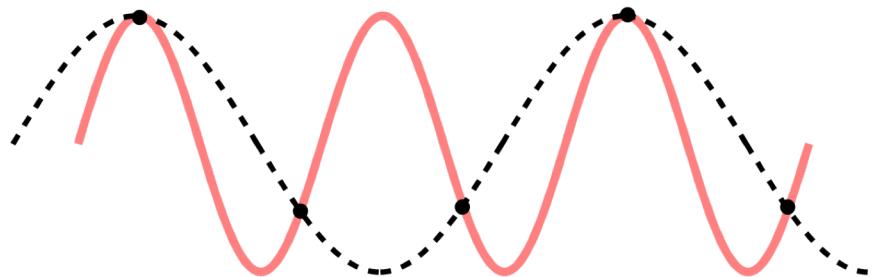
LTI systems
Fourier analysis
A-to-D sampling
Z and Laplace Transforms

Signals & Systems

Fourier Analysis & Decomposition

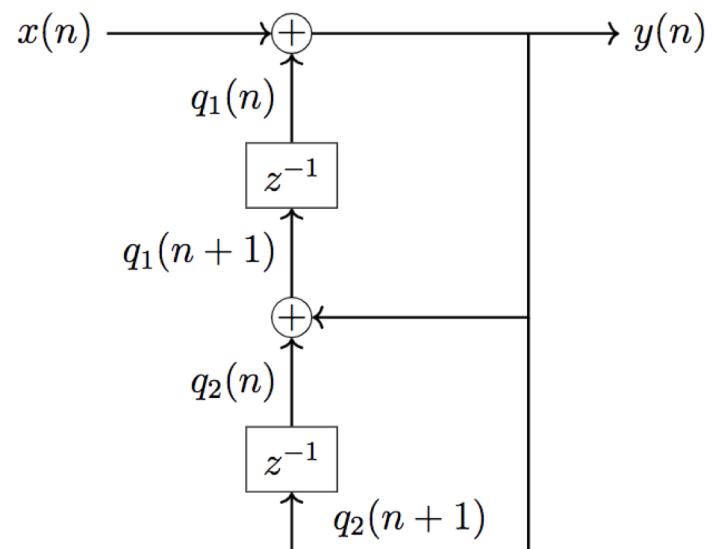


Sampling Theory



Systems: Fibonacci Seq. Generator

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



$$x(n) = 1, 0, 0, 0, 0, 0, \dots$$

$$y(n) = 1, 1, 2, 3, 5, 8, \dots$$

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:

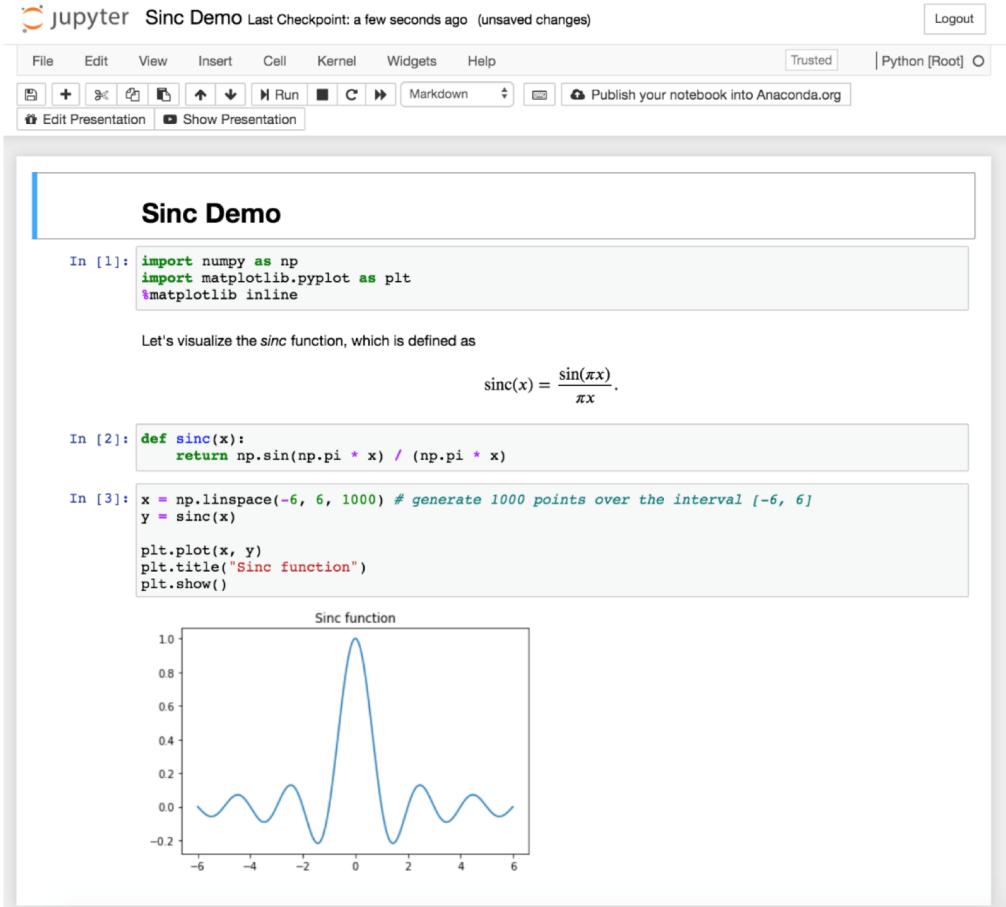
- Applications-driven
- Teach computational skills
- Self-contained

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 screenshot shows a Jupyter Notebook interface titled "Sinc Demo". The top navigation bar includes "File", "Edit", "View", "Insert", "Cell", "Kernel", "Widgets", and "Help". It also features a "Logout" button, a "Trusted" status indicator, and a "Python [Root]" option. Below the toolbar are standard notebook controls for cell selection, running, and publishing.

The main content area is titled "Sinc Demo". It contains three code cells:

- In [1]:

```
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
```
- In [2]:

```
def sinc(x):
    return np.sin(np.pi * x) / (np.pi * x)
```
- In [3]:

```
x = np.linspace(-6, 6, 1000) # generate 1000 points over the interval [-6, 6]
y = sinc(x)

plt.plot(x, y)
plt.title("Sinc function")
plt.show()
```

Below the code cells is a plot titled "Sinc function" showing the graph of the sinc function, which is zero at all integer multiples of pi and has a maximum value of 1 at x=0.

The Jupyter Notebook

Mathematically, we represent a note with frequency f as a sine wave at that frequency with some amplitude A and phase ϕ ,

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

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

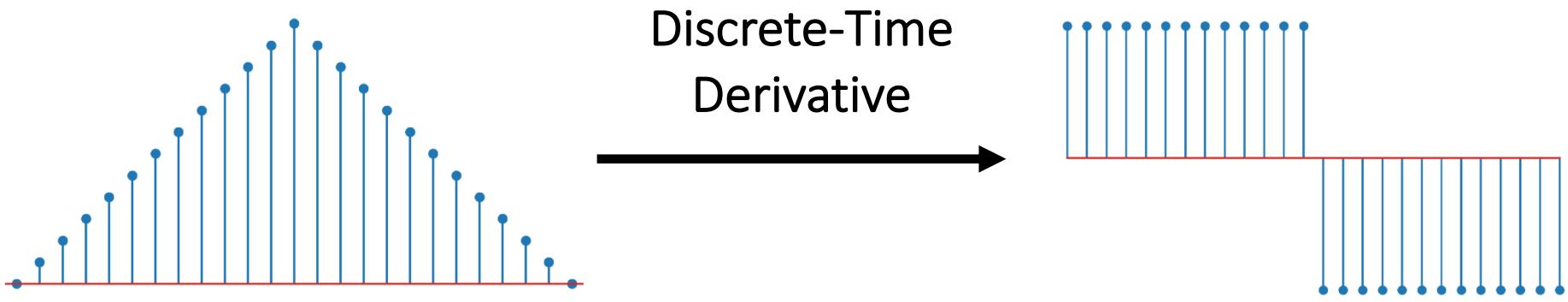


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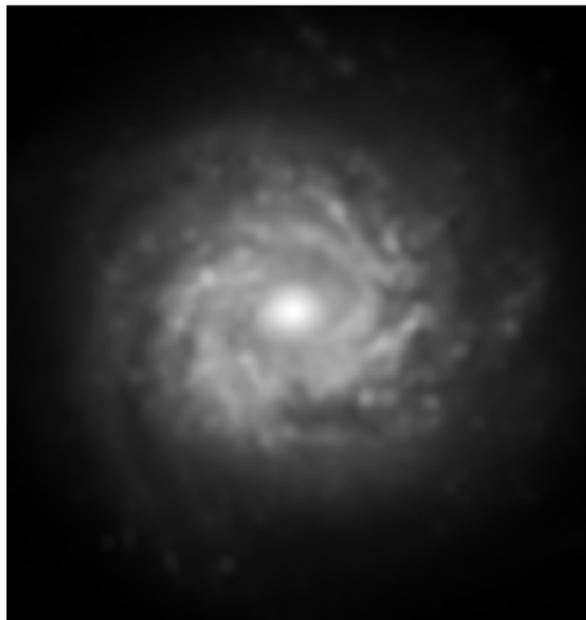
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Applications-Driven Labs

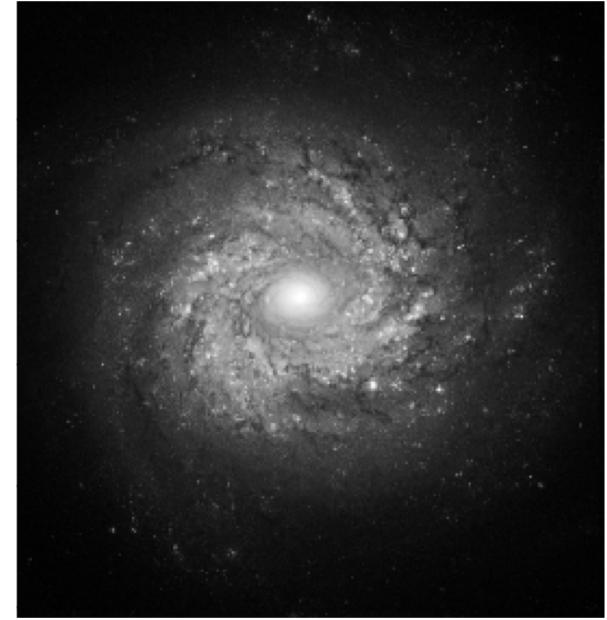


Finite-Difference Filter for Numerical Differentiation

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



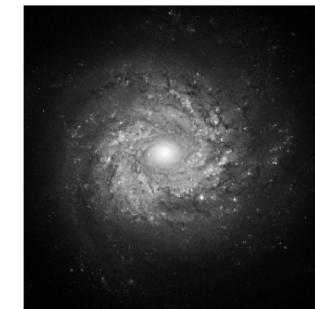
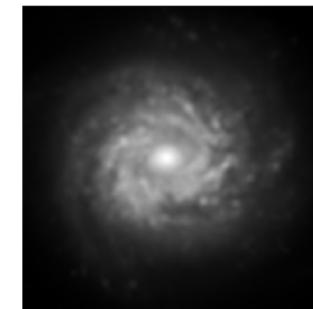
(Current Best) RMSE: 1.962, Sigma: 5.102, Kernel Size: 15

Original RMSE: 12.303

Best RMSE: 1.962

Parametric sweep gives a 6.27x better result.

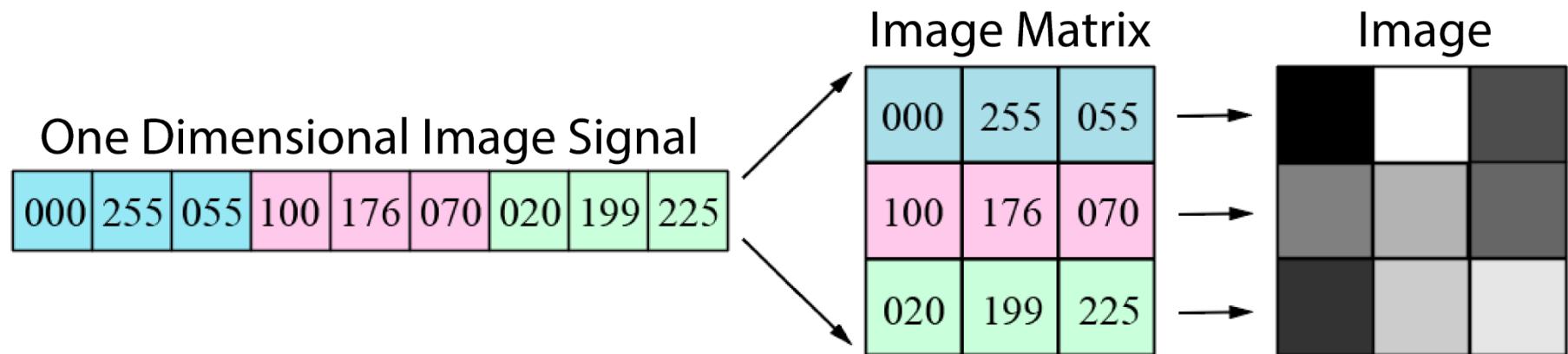
Blurry



Deblurred

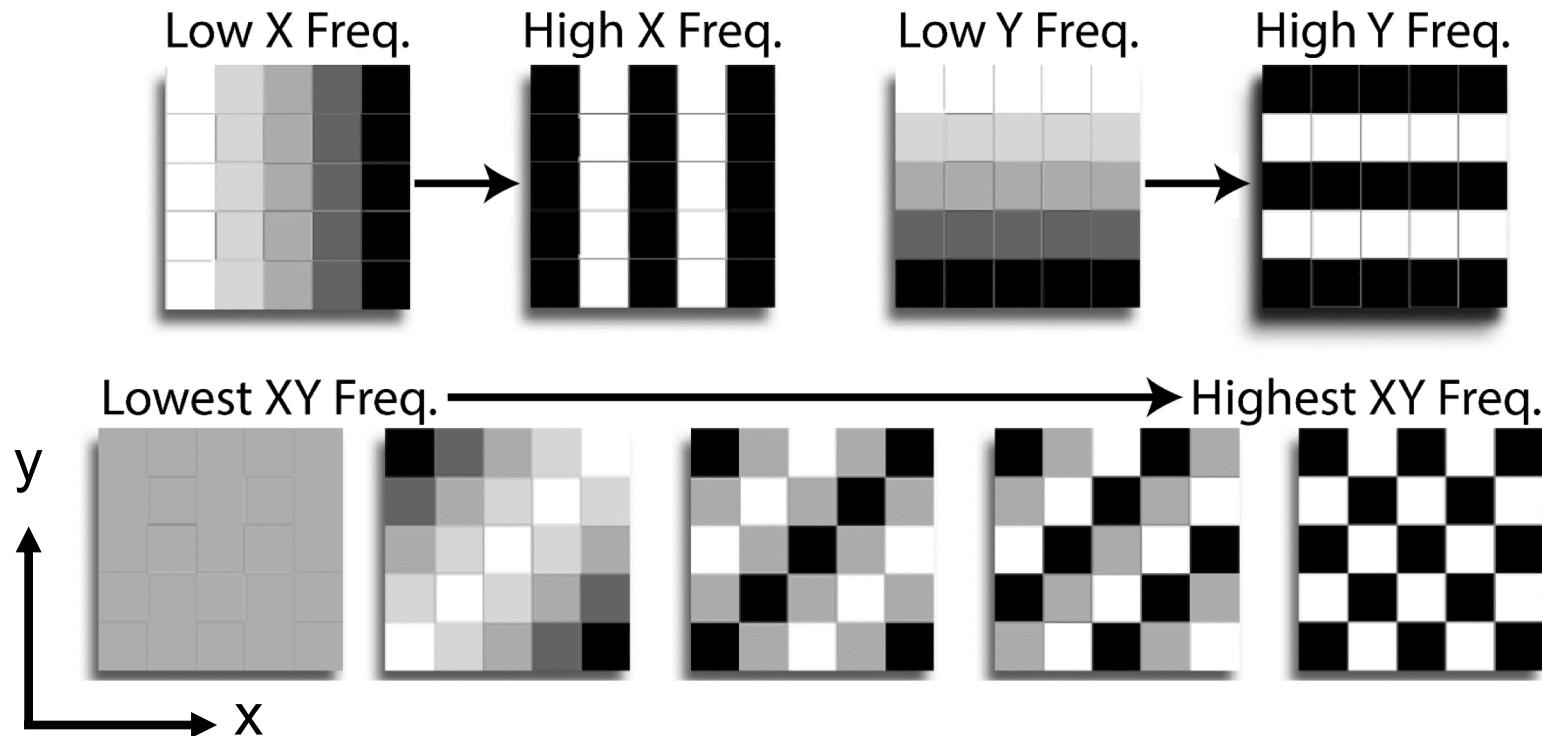
Use a parametric sweep for numerical optimization

Self-Contained Labs



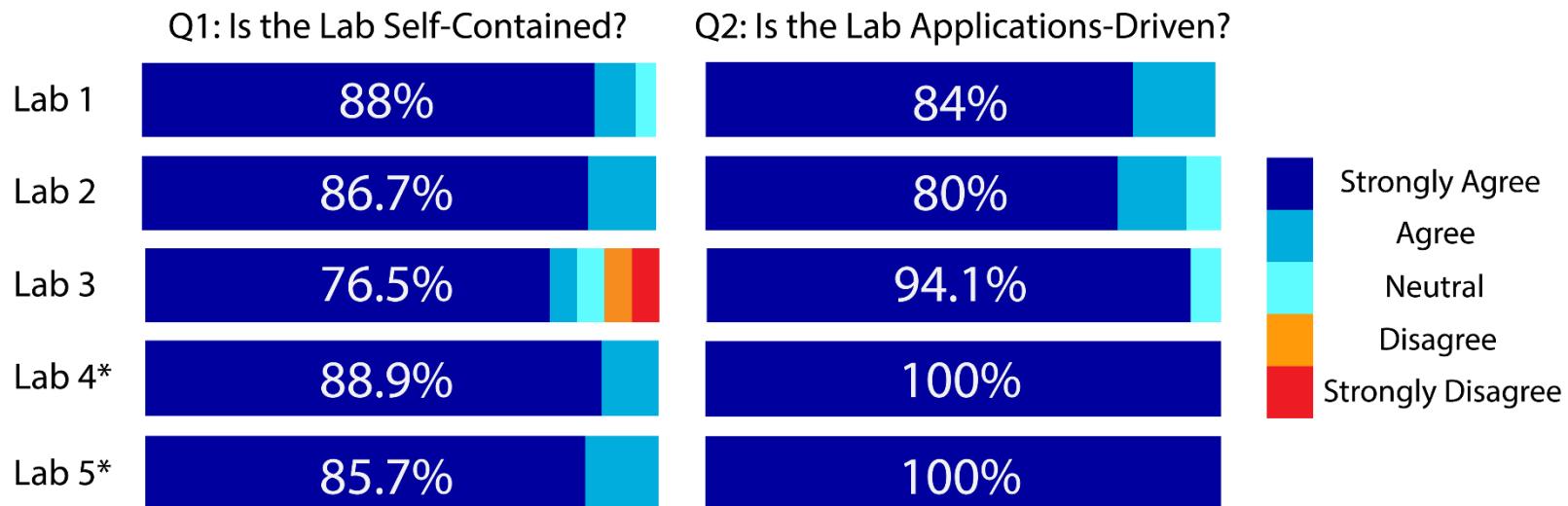
Generalize 1D signals to 2D signals

Self-Contained Labs



Generalize 1D frequencies to 2D frequencies

Student Feedback



*lower response rate due to COVID-19

Spring 2020 student feedback