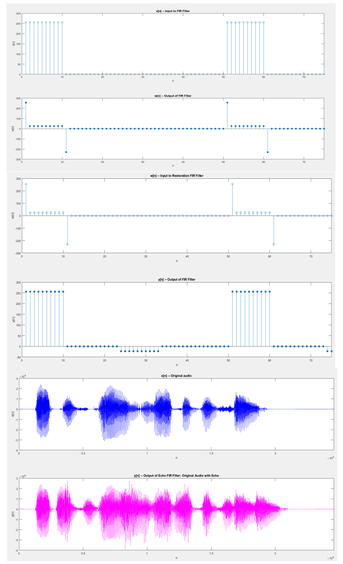
Exploring FIR Filters

Logan Barnes, Spencer Durrant,
Bailey Martin, Luke Neumann

University of Utah, ECE Department

Deconvolution and Echos with 1-D Filters

- A first-order difference FIR filter h[n] = d[n] - 0.9d[n] is applied to x[n] resulting in w[n] = x[n]-0.9x[n] using the firfilt() function.
- A restoration FIR filter is applied to deconvolute w[n] to y[n], which, should be nearly identical to x[n].
- An echo i $y[n] = \sum_{\ell=0}^{M} r^{\ell} w[n-\ell]$ = x[n]+rx[n-P], where r = 0.9 for 90% amplitude and P = 1600 for a 0.2 second delay due to sample rate of 8k Hz.



Introduction

A FIR filter can be used to restore a signal altered by another FIR filter in a process called deconvolution.

Echos (or "ghosts" for images) can be produced by FIR filters.

First-difference FIR filters are used for edge detection of images: they have zero output for a constant input, but a large output when the input deviates.

Barcode scanner

- Bar codes contain 12 digits of alternating black and white bars
- UPC (Universal Product Code) uses widths of bars to encode numbers
- The thickest bar is 4 widths, thinnest bar is 1 width or Θ (theta). There is a total of 59 bars
- Each number is encoded as a quadruplet of 0-9
- Encoding for each number must add up to seven, so every bar code total width is the same at 95 units – including unique delimiters

```
0 = 3-2-1-1        5 = 1-2-3-1
1 = 2-2-2-1        6 = 1-1-1-4
2 = 2-1-2-2        7 = 1-3-1-2
3 = 1-4-1-1        8 = 1-2-1-3
4 = 1-1-3-2        9 = 3-1-1-2
```

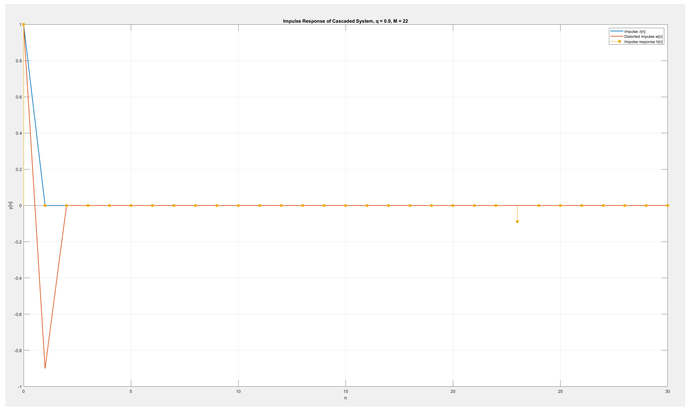

```
Trimmed bar code:
1 1 1 1 2 1 3 1 2 1 3 2 1 2 2 1 3 1 2 1 2 1 3 3 2 1 1 1 1 1 1 1 1 1 3 2 1 2 3 1 3 2 1 1 2 2 2 1 1 1 1 4 1 2 3 1 1 1 1
```

Cascading Two Systems

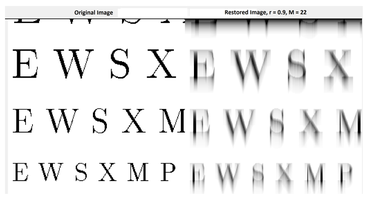
- More complex systems are often created from combining simpler 'building blocks'
- Here, we are combining two filters 'in cascade'
- The first filter introduces distortion
- The second filter attempts to recover the distorted signal

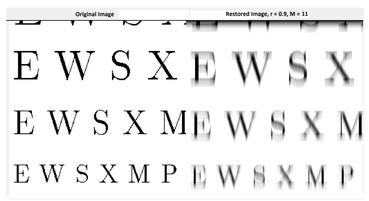
$$w[n] = x[n] - q\,x[n-1] \qquad \text{(FIR Filter-1)}$$

$$y[n] = \sum_{\ell=0}^{M} r^{\ell} w[n-\ell] \qquad \text{(FIR Filter-2)}$$



- Notice that when M=22, there is more distortion in the recovered image than when M=11
- This could be because with longer filter lengths, more distortion can be included in the summation, resulting in more distortion in the final recovered signal





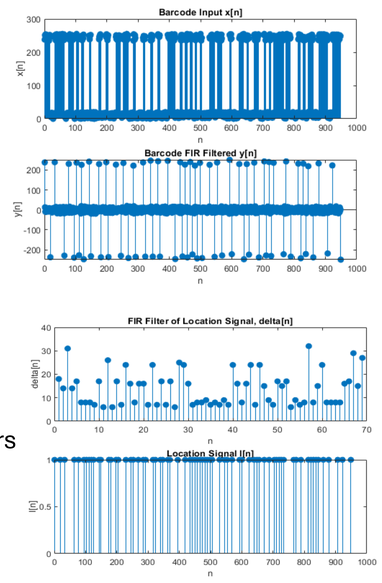
Finding Edges: 1-D Filter Cascaded with Nonlinear Operators

- The given FIR filter y[n] = x[n] - x[n-1] outputs the difference between the current and previous data points.
- The coefficients of the FIR filter are [1 -1]
- When the FIR coefficients are convolved with the input signal the filtered output is obtained.
- An edge will appear if there is a large change between the current and previous data point such as transition between 0 and 255.
- This FIR filter is essentially a high pass filter as it only lets edges pass to the output.
- The length of the output signal after convolution will be L=N+M–1, M is the input sequence length and N is the filter length.
- With this data set the length of y[n] is 159 + 2 - 1 = 160.
- Use a non-linear operator to show where an edge occurs in the signal.
- d[n] = abs(y[n]) > threshold, This formula converts the output into a location signal.

Barcode Detection and Decoding

How can we use FIR filters to detect and decode a bar code?

1. Take a simple barcode image, and take a sample row – x[n]
2. Filter with first-difference (like a derivative) FIR filter
3. Convert signal to a sparse location signal l[n] – indices in x[n] that are actual edges
4. Apply first-difference FIR filter again to l[n] and calculate differences/derivatives for Δ[n] - shows the widths of all the bars
5. Estimate Θ, clean up the signal as needed, and then decode using UPC



Conclusion

FIR filters are useful tools that enable applications such as edge detection, deconvolution, and barcode scanning. We demonstrated how FIR filter can also produce artifacts like echos, as well as how to restore signals and extract meaning. FIR filters are practical for use in many real-world applications.

Contributions

Deconvolution and Echos (ghosts) with FIR filters – Bailey & Logan

Finding Edges and Barcode Scanner – Luke & Spencer