Medical Imaging Notes

ELC5396

Spring 2025

Lecture by Professor Keith Schubert, Notes by Chris F Lin

1 Tuesday 1/2/2025

- examples of medical imaging: MRI, Ultrasound(US), XRay, CT, PET, Mass Spec, SPECT, DOT, anger cameras
- a modality: danger vs safe. what's a breakpoint?
  - use 13.6 eV: energy in UV light
  - This is the energy needed for an electron in a single H atom to get free; we call this *ionizing energy*. Since human body is water (and thus mostly hydrogen), UV is minimum energy to ionize hydrogen (called ionization). Once all the oxygen is ionized, it has a chance to bond with other cells. If too many links break, the cell dies due to ionized oxygen damaging DNA. So 13.6 eV can/can't ionize cells, damaging or not damaging DNA.
- Another break point: how to take an image: three times
  - **transmission**: source outside, receiver on other end
  - **reflective**: source and receiver outside, same location
  - **emission**: source inside object receiver outside

2 Thursday 1/23/2025

- Signals and systems, what's the thought?
  - *convolutions*: allow us to determine system characteristics.
  - simply "multiplication"
- **Convolution**: $*$ operator
  - $h(n) = f * g(n) = \sum_m f(n)g(m-n)$
    - $-n$ is reflection, $+m$ shift in time
    - integration for continuous function
    - important takeaway: we're worrying about many shifts (which correspond with the index)
  - If our example is $[1,2,1] * [2,1] = [2,5,4,1]$
    - Another way of interpretation?
    - polynomial multiplication; $(1+2x+x^2)(2+x) = 2+5x+4x^2+x^3$
    - makes for easy way to perform polynomial multiplication!

- $O(n^2)$ operation
- for medical images, each pixel considered its own dimension, so operation complexity is important
- instead of performing convolution which is $O(n^2)$, maybe we can take FT since we like working in multiplication
- $F(f(t) * g(t)) \rightarrow F(u)G(u)$ fourier transform
  * from convolution to point-by-point multiplication or *array multiplication*
  * So we go from $O(n^2)$ to $O(n)$ for the operation complexity
  * but we have to account for FT calculation; this is $O(n^2)$
  * instead of basic FT, can use FFT, accelerates to $O(nlogn)$ by taking advantage of FT and splitting into binary tree
  * random fact, $log(n)$ is slowest growing function that grows to infinite
- introduce emphasis on speed: we want fast performance
- Figure 1 for system in series
  * $g_0 = h_1 * f$ fed into H_2 so $g = (h_2 * h_1) * f$
  * can turn into one big box: $G = H_1 H_2 F$
  * this setup is in *series*

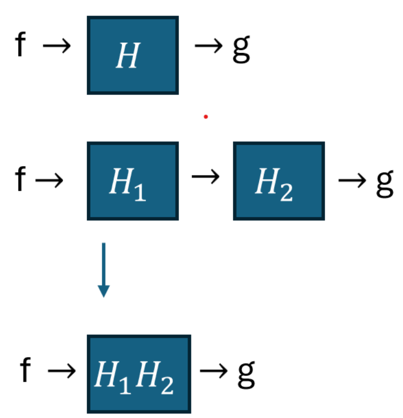

Figure 1: Systems in Series

- Figure 2 parallel system
  * Other setup in *parallel*
  * $g = h_1 * f + h_2 * f = (h_1 + h_2) * f$

- Some systems we like: *LTI (time invariant)* or *LSI (space invariant)*; difference is with variable we deal with. typically will work with shift invariant in this course, rarely deal with time only. shifts can be in space and time.

- some other helpful functions and properties
  - Say we want ot calculate FT of image. in general, we say it's $O(n^2)$
  - if our image is n by n, then the FT is $O(n^4)$

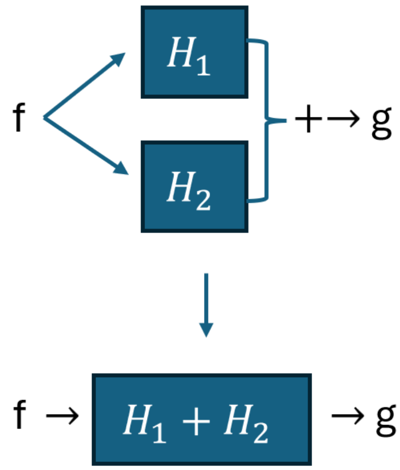

Figure 2: Systems in Parallel

- instead of FT in both directions at once, we can simplify to FT in x direction then in y direction due to separability of the FT operation

- so far, have threre important properties: linear, shift invariant, and separable.
  - if we ask to a system is *linear*, we check for *additive* and *scalar* properties
  - checking for *shift invariant*, we check for $G(f(x + \Delta x)) = g(x + \Delta x)$