Material decomposition using neural network for PCDs

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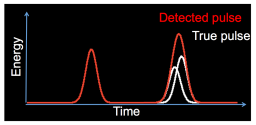
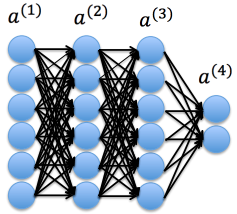
Motivation



Photon counting detectors (PCDs) detect individual photons and discriminate them into multiple energy bins. This energy information provide benefits including improved image quality and better tissue characterization. A major problem with PCDs is the slow count rate, resulting in count rate loss (photons arriving too close in time are recorded as only one event) and pulse pileup (detected energy of that event is incorrectly higher or lower). These effects cause spectral distortion, which impairs material decomposition accuracy.

Neural network



$$a^{(1)} = \begin{bmatrix} 1 \\ x \end{bmatrix}$$

$$a^{(2)} = \begin{bmatrix} 1 \\ g(\Theta^{(1)} a^{(1)}) \end{bmatrix}$$

$$a^{(3)} = \begin{bmatrix} 1 \\ g(\Theta^{(2)} a^{(2)}) \end{bmatrix}$$

$$a^{(4)} = h_\theta(p) = \Theta^{(3)} a^{(3)}$$

We want to estimate basis material thickness from distorted measured spectra.

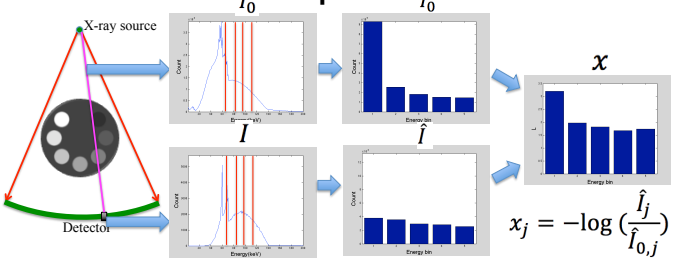
Input x : Measured spectrum (assume 5 energy bins)

Output y : Thickness of basis materials (water and calcium)

Cost function :

$$J(\theta) = \frac{1}{2m} \sum_{i=1}^{m} \sum_{k=1}^{K} \left(h_\theta(x^{(i)})_k - y_k{}^{(i)}\right)^2 + \frac{\lambda}{2m} \sum_{i,j,l} \left(\Theta_{ij}{}^{(l)}\right)^2$$

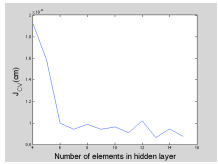
Input



$$x_j = -\log\left(\frac{\hat{I}_j}{\hat{I}_{0,j}}\right)$$

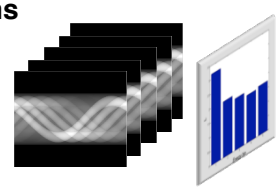
Test different number of elements in hidden layer (for network with one hidden layer) by cross validation with 3060 examples

So, choose 13 for number of elements

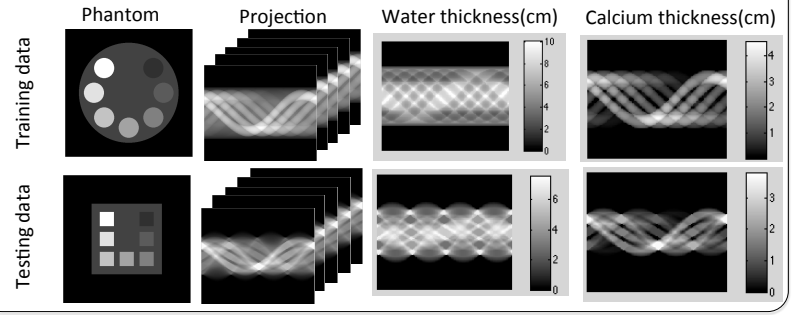


Simulations

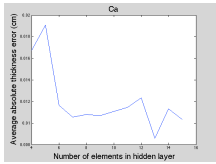
Two phantoms are scanned to acquire projection measurements (180 views, fan-beam geometry). The measured spectra are then distorted using our implementation of an analytical model of pulse pileup effect [1].

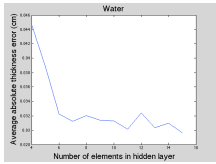


Phantoms : water phantom with 8 inserts of calcium with density from 0 to 1.550 g/cm^2

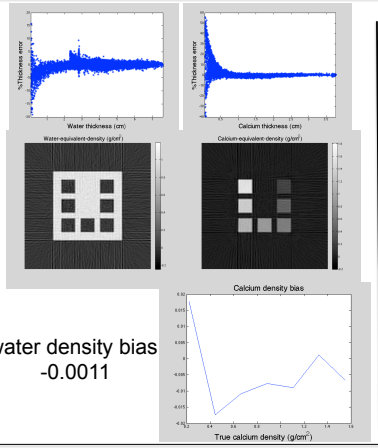


Results



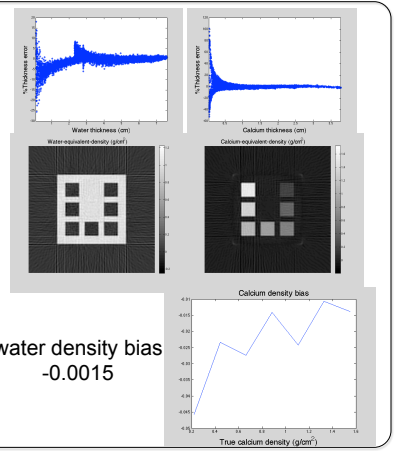


Network with 1 hidden layer (#elements of hidden layer = 13)



water density bias -0.0011

Network with 2 hidden layers (#elements of hidden layer = 3, lambda=0.01)



water density bias -0.0015