ETH Zürich
D-ITET
Biomedical Engineering

Master Studies

Biomedical Imaging

Homework #8 - Nuclear Imaging 1

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1 Task 1

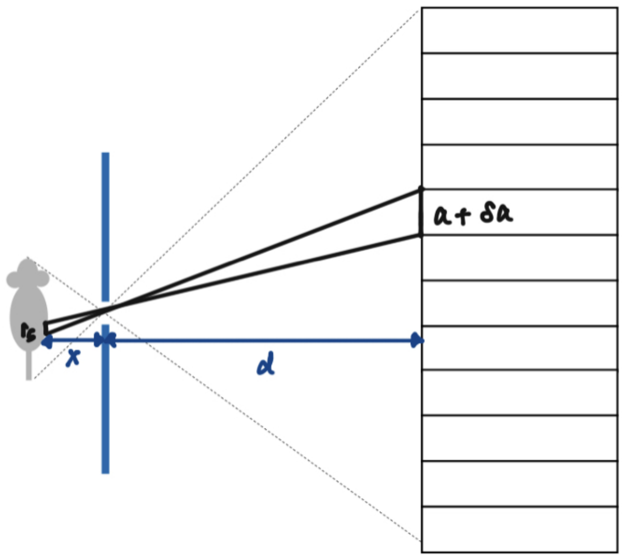

Figure 1.1: Ideal Pinhole w/ Object of Negligible Thickness

As is shown in Figure 1.1,

$$\frac{r_s}{a+\delta a} = \frac{x}{d} \tag{1.1}$$

Thus,

$$x = \frac{r_s d}{a+\delta a} = 40mm \tag{1.2}$$

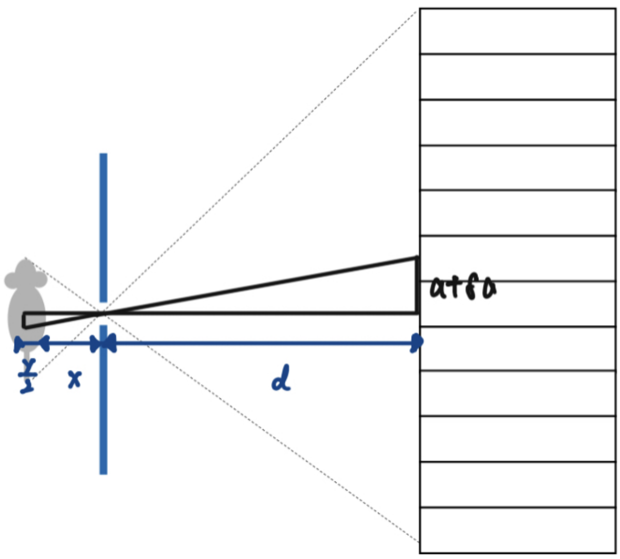

Figure 1.2: Ideal Pinhole w/ Object of Non-negligible Thickness

As is shown in Figure 1.2,

$$\frac{r_s}{a+\delta a} = \frac{x+\frac{y}{2}}{d} \tag{1.3}$$

Thus,

$$r_s = \frac{(a+\delta a)(x+\frac{y}{2})}{d} = 0.9mm \tag{1.4}$$

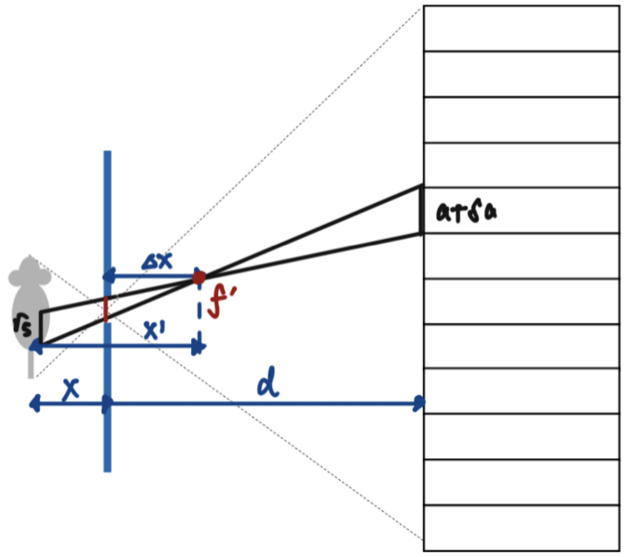

Figure 1.3: Actual Pinhole w/ Object of Negligible Thickness

When the diameter of the pinhole is not negligible, the focal point will move away from the pinhole.
As is shown in Figure 1.3,

$$\frac{d_{pinhole}}{a+\delta a} = \frac{\Delta x}{d-\Delta x} \tag{1.5}$$

Solving for Δx, we obtain,

$$\Delta x = 6.45mm \tag{1.6}$$

Thus,

$$\frac{r_s}{a+\delta a} = \frac{x'}{d-\Delta x} \tag{1.7}$$

Solving for x' we obtain,

$$x' = 38.71mm \tag{1.8}$$

Thus, the distance between the object and the pinhole now is given by,

$$x_{new} = x' - \Delta x = 32.26mm \tag{1.9}$$

2 TASK 2

The results are shown in Figure 2.1

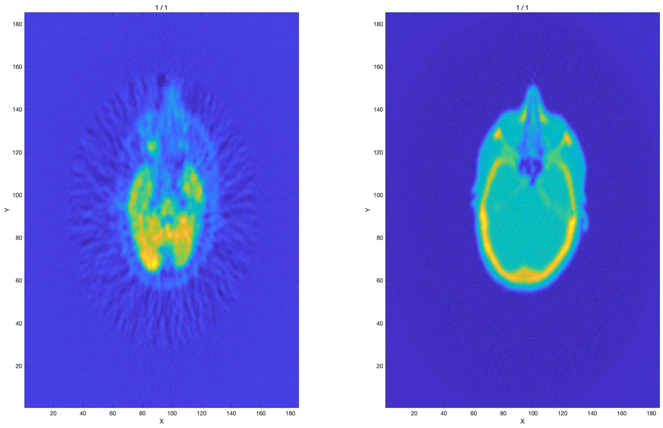

Figure 2.1: PET and CT Images

As is shown in figure 2.1, the tracer accumulates in brain grey and white matters.
The relationship is given by,

$$HU = \frac{\mu - \mu_{water}}{\mu_{water}} 1000 \tag{2.1}$$

3 TASK 3

The reason for the drop of reconstructed activity is that not all the annihilation events can be detected because the photons will be attenuated while penetrating the human body. The probability is given by,

$$p(x) = e^{-\int \mu x dl} e^{-\int \mu (d_{LOR} - x) dl} = e^{-\int \mu d_{LOR} dl} \tag{3.1}$$

We can easily see that the probability is independent of the location of annihilation within LOR.
The attenuation correction is given by,

$$C = e^{\int \mu d_{LOR} dl} \tag{3.2}$$

The results are shown in Figure 3.1.

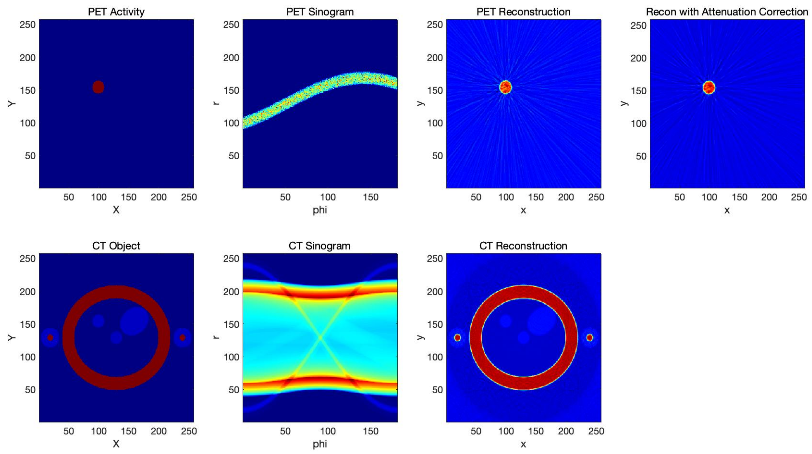

Figure 3.1: PET and CT Images

The results suggest that with correction the tumor activity increases from 225 to approximately 300, which is around the activity value of ground truth.
The potential difficulties are:

- The resolution of CT is independent of the depth of the tissue. Also it is higher than that of PET(typically one order of magnitude higher). Thus, interpolation is required to match the matrix size where spatial mismatch is likely to occur.
- Respiratory movements: for lung, it will cause differences in attenuation distribution.
- Patient movement: misalignment of the PET and CT images will distort the boundaries.