Exercise NUC #1 – SPECT and PET/CT
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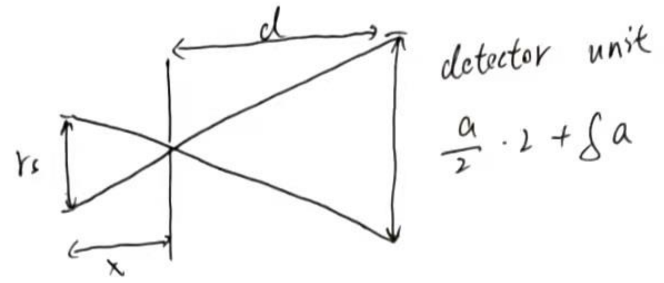
Task 1.1 (SPECT)

①



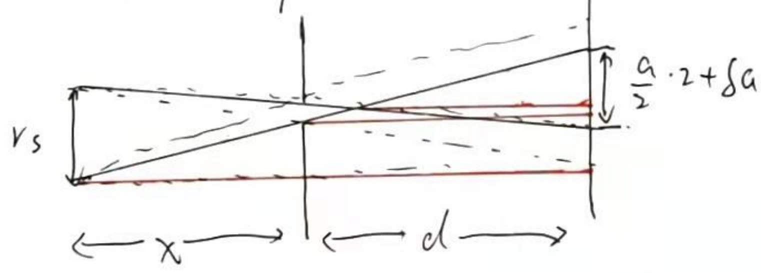
$$\frac{r_s}{x} = \frac{\frac{a}{2}\cdot 2+\delta a}{d} \qquad x = 40mm$$

②

$$\frac{r_c}{x+\frac{y}{2}} = \frac{\frac{a}{2}\cdot 2+\delta a}{d}$$

$$r_c = 29mm.$$

③

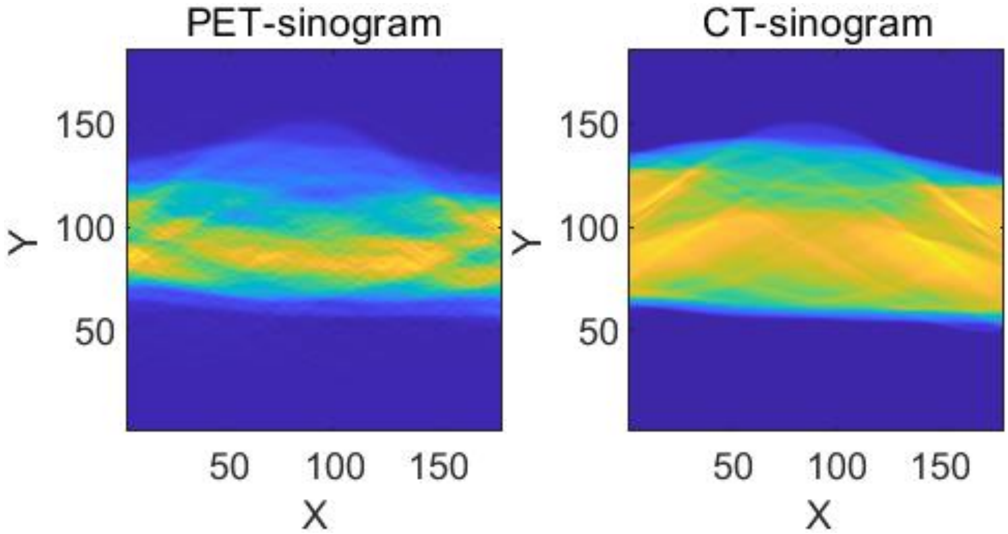


$$\frac{d}{x+d} = \frac{\frac{1}{2}(\frac{a}{2}\cdot 2+\delta a)+\frac{1}{2}\cdot d_{pin}}{\frac{1}{2}r_s + \frac{1}{2}(\frac{a}{2}\cdot 2+\delta a)}$$

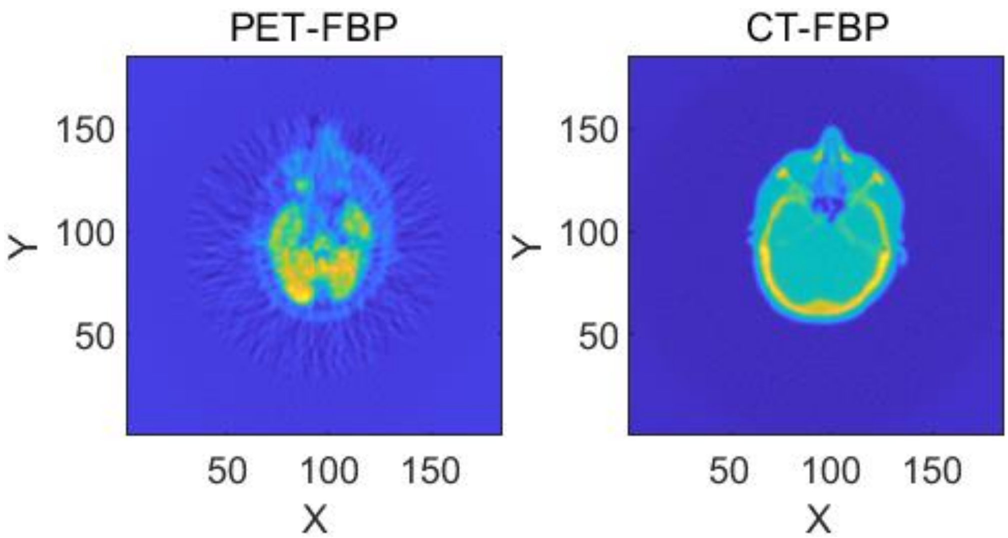
$$x = 32.26mm$$

Task 1.2 (PET)

Sinograms in the in-vivo data:



FBP results:



The result shows that the PET tracer mainly accumulates in the area of cerebrum.

The linear attenuation coefficients can be calculated according to the definition of CT numbers:

$$CT_O = 1000\frac{\mu_O - \mu_{H_2O}}{\mu_{H_2O}}$$

In this task, we can get the linear attenuation coefficients using the following codes:

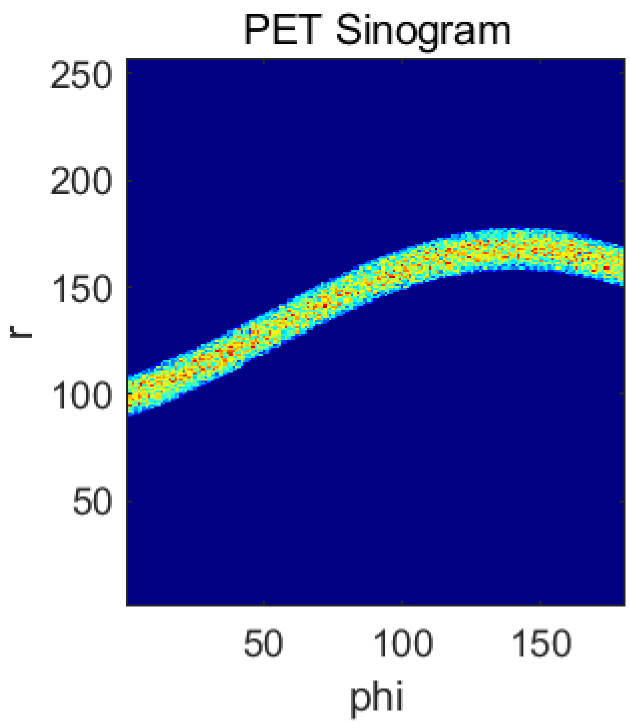
```
% Calculate linear attenuation coefficients from HU data
mue_water = 1.707E-01;                    % water  @ 100 keV  [/cm]
invivo.mue = invivo.ctfbp*mue_water/1000;
```

Task 1.3 (PET)

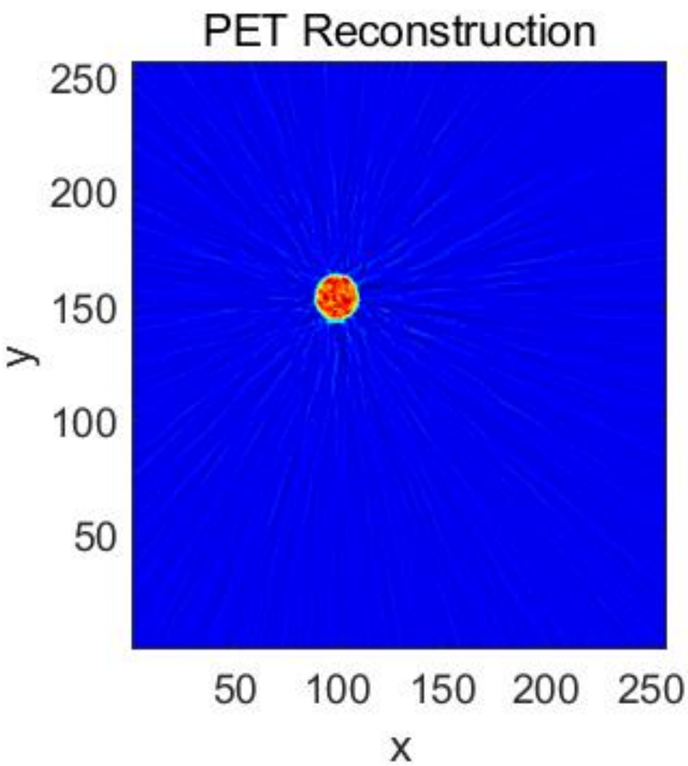
Update mass attenuation coefficients of the PET section and assign a radioactivity of 300MBq to the lung tumor:

```
phantom.ellipse = [    0    0    90   80   0    mue_bone(2)                  0;      % thorax
                       0    0    70   60   0    mue_lung(2)-mue_bone(2)      0;      % lung
                    +110    0    15   15   0    mue_muscle(2)                0;      % left arm muscle
                    +110    0     5    5   0    mue_bone(2)-mue_muscle(2)    0;      % left arm bone
                    -110    0    15   15   0    mue_muscle(2)                0;      % right arm muscle
                    -110    0     5    5   0    mue_bone(2)-mue_muscle(2)    0;      % right arm bone
                       0    0    10   10   0    mue_blood(2)-mue_lung(2)     0;      % aorta
                     +30  +25    25   20  35    mue_muscle(2)-mue_lung(2)    0;     % heart
                     -30  +25    10   10   0    mue_muscle(2)-mue_lung(2)    300];   % lung tumor
% Task 1.3.          -30  +25    10   10   0    mue_muscle(2)-mue_lung(2)    yyy];   % lung tumor
```

PET Sinogram:



FBP Reconstruction:



Radioactivity in this reconstruction and the ground truth:

```
PET tumor activity ground truth: 300.000000
PET tumor activity w/o correction: 265.819915
```

This discrepancy mainly comes from the attenuation of γ-rays. When γ-rays are passing through the body, they will be attenuated by tissue. In this way, the detected PET tumor activity will decrease.

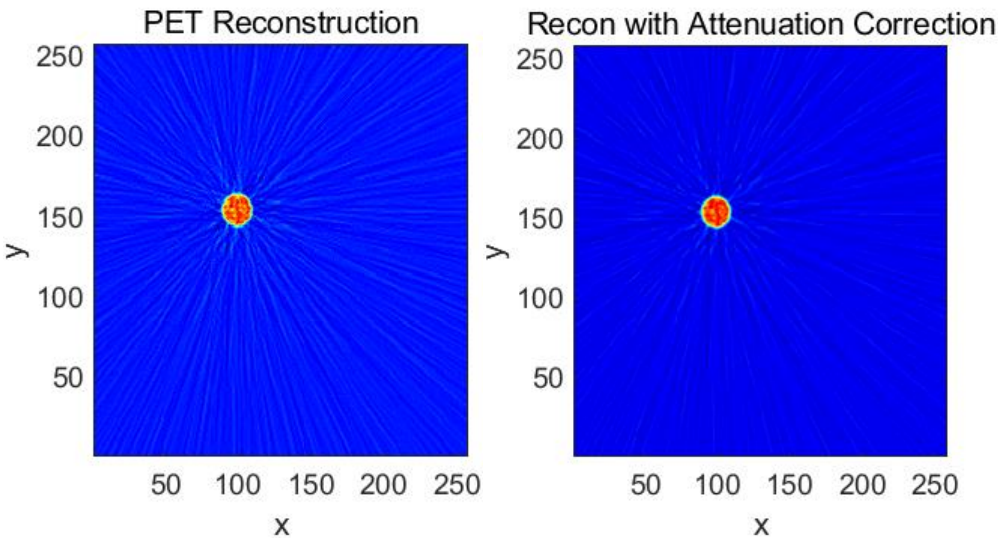
To deal with the problem, we should get the distribution of the linear attenuation coefficients for γ-rays. One way is to estimate them using a linear approximation:

$$\eta_{CT\to PET} = \frac{\mu_{PET\_bone} - \mu_{PET\_water}}{\mu_{CT\_bone} - \mu_{CT\_water}}$$

Using this equation, we can calculate the conversion factor and then use it to estimate the linear attenuation coefficients for γ-rays. Then use the following equation to implement attenuation correction.

$$sino_{PET\_corr} = sino_{PET\_original} * e^{sino_{CT} \times \eta_{CT\to PET}}$$

Results after setting the linear attenuation of bone to 10x the original value:



And the radioactivity after correction is close to the ground truth:

```
PET tumor activity with correction: 294.924684
```

There are some potential difficulties of PET attenuation correction clinical practice[1]. First, considering that the spatial resolution of CT is always better than PET, the corrected images may have more noises after using CT images to implement the attenuation correction. One way to deal with the problem is to use data interpolation. What's more, potential motion of the patient may lead to motion artifacts. In clinical experiments, CT examinations are followed by PET examinations, which means the imaging time slots are not the same. Even if the patient controls his/her body stably, there will still be some involuntary movements, such as respiration and heartbeat. We need to design the imaging timing carefully to attenuate the motion artifacts.

[1] Rahmim, Arman, and Habib Zaidi. "PET versus SPECT: strengths, limitations and challenges." Nuclear medicine communications 29.3 (2008): 193-207.