ScoutIT: Interior Tomography using Modified Scout Acquisition

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1. INTRODUCTION

Xia et al.[?] recently reported a method to improve image quality in truncated volume-of-interest (VOI) imaging using anterior-posterior (AP) and medio-lateral (ML) scout views. Their work was applied to C-arm based imaging, and relied on the assumption that the scout views cover the entire object, while the final VOI scan is severely truncated. In clinical computed tomography (CT), it is quite common that both the AP scout view and the final tomographic scan are moderately truncated, but the ML scout view is not truncated. This paper shows that acquiring AP scout views with a modified configuration allows accurate interior tomography for a truncated tomographic CT scan.

2. METHODS

2.1 Modified scout configuration

Figure **??**A shows a normal scout configuration. The technologist typically attempts to align the patient at the iso-center (patient centering might not be accurate, and is typically improved through information gathered through the scouts). The source-to-(assumed)-iso-center distance is noted as D_0 in the figure. For patients whose body-habitus does not lie within the FFOV of the scanner, the truncation predominantly arises in the AP direction but the lateral (ML) scouts are not truncated.

As shown in Fig. **??**B, we propose a modified scout acquisition. While the lateral (ML) scouts are acquired in the original configuration, the AP scouts are acquired after moving the table down by a distance d (there is of course a limit to how far the table can move down in the gantry). By moving the patient table down, the geometric magnification at the detector changes, and a larger patient habitus can be covered by x-ray beam. The modified AP scout configuration allows acquisition of non-truncated AP projections up to an extended body habitus of length L_{eff}, where:

$$L = \frac{D}{D_0} \times FFOV \tag{1}$$

We calculate the value for L_{eff} for four CT scanners whose geometric specifications were reported in.[?] We make the following assumptions:

- the AP scouts are typically acquired at or near the actual iso-center
- the patient table can be moved down in the gantry by at least 150 mm; this appears to be a realistic estimate as the bore radius is greater than 400 mm for all the scanners in list below

Table **??** provides a list of relevant geometric specifications reproduced from,[?] the resulting value of L_{eff} for a table displacement $d = 150mm$, and the resulting percentage increase in patient habitus coverage.

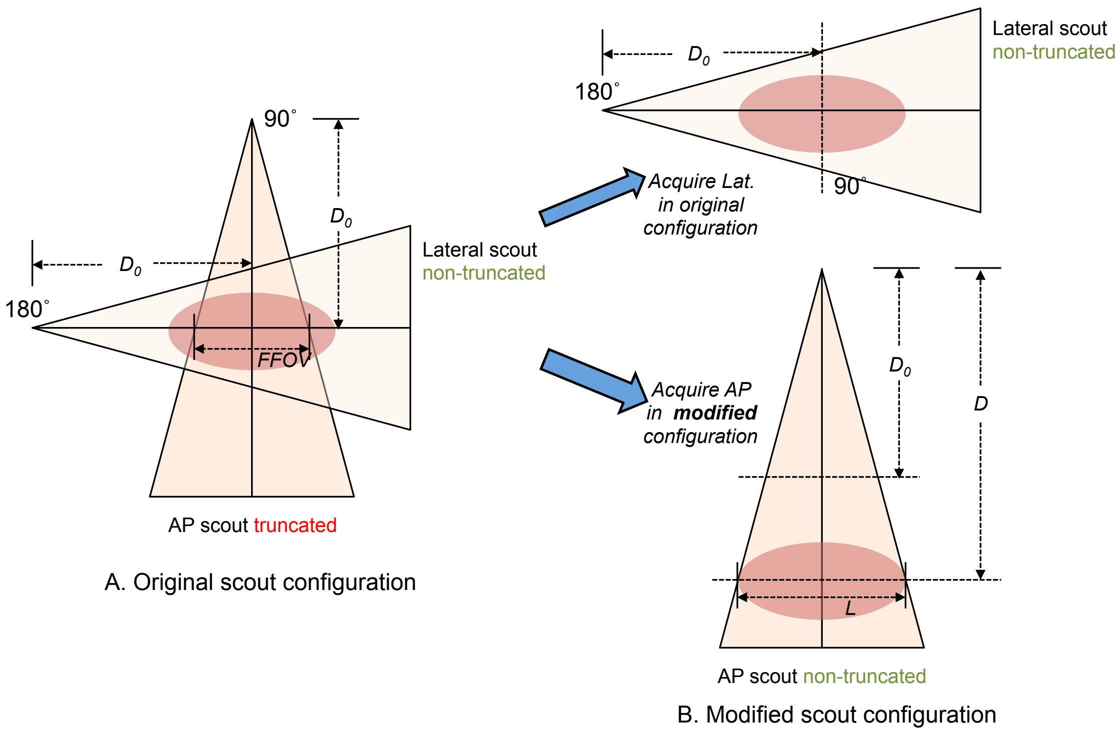

Figure 1. Block diagram for two-pass metal artifact reduction algorithm (MAR2)

	GE LSX	Philips Br.	Siemens SOM.	Toshiba Aq.
Aperture [cm]	80	85	82	90
Focus-isocentre distance [mm]	606	645	570	712
Focus-detector distance [mm]	1062.5	1183	1040	1275
Maximum reconstruction field of view	50	50	50	50
Reconstruction matrices	512×512	512×512	512×512	512×512
L_{eff}	62.37	61.63	63.15	60.53
% increase	24.75	23.26	26.32	21.07

Table 1. Geometric specifications of four different CT scanners and corresponding values of increased patient coverage L_{eff}

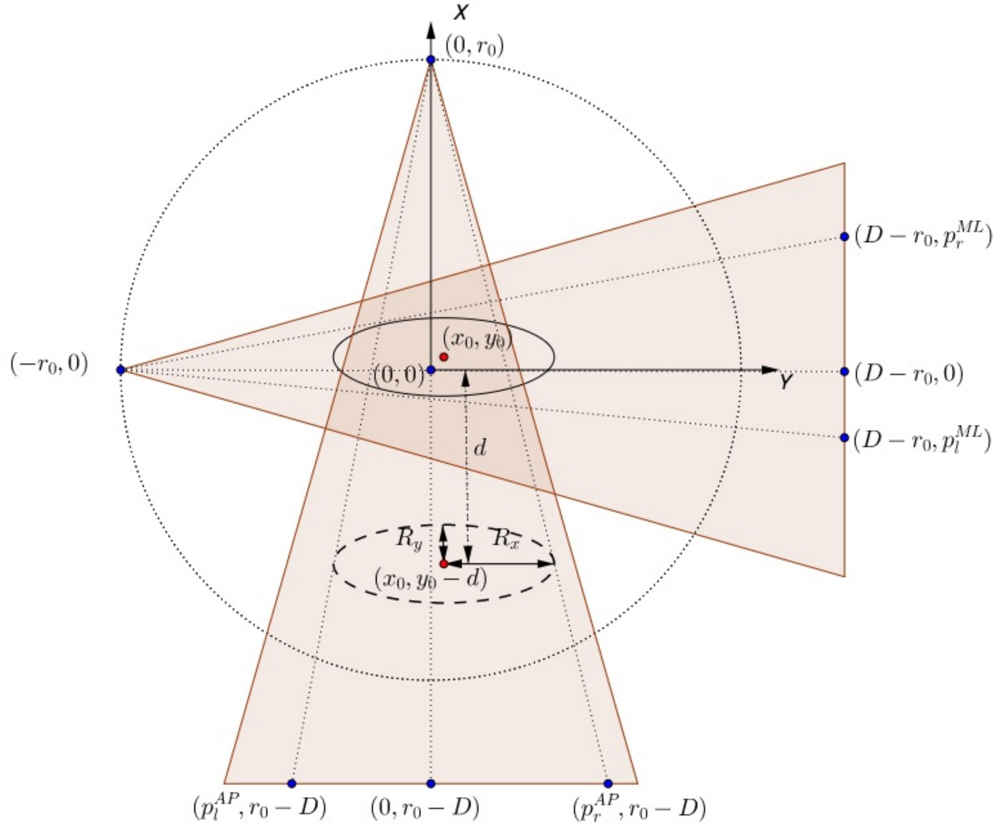

Figure 2. Setup for acquisition of ML scout in original configuration and AP scout in modified configuration

2.2 Patient shape model estimation using slice-wise ellipse

In our setup shown in Fig. **??**, we place the origin of our co-ordinate axes $(0, 0)$ at the scanner iso-center. The source-to-iso-center distance is r_0 and the source-to-detector distance is D. Thus, the source is at $(0, r_0)$ when acquiring the AP view, and at $(-r_0, 0)$ when acquiring the ML view. The patient's body habitus in the slice represented in this diagram is estimated as an ellipse with center (x_0, y_0) and major and minor axis lengths of (R_X, R_y) respectively.

As shown in the figure, the lateral (ML) scout is non-truncated in the original acquisition configuration. However, the AP scout would be truncated in this original configuration. By lowering the patient table by a distance d, the truncation is avoided. The projection of the iso-center, and tangents to the ellipse in the original ML scout and the modified AP scout are marked in the figure. In practice, these values are available from measurements on the acquired scout views.

We calculate the slopes of the four tangents to the ellipse in ML and modified AP scout views as:

$$\begin{aligned}
m_l^{AP} &= \frac{-D}{p_l^{AP}} \\
m_r^{AP} &= \frac{-D}{p_r^{AP}} \\
m_l^{ML} &= \frac{p_l^{ML}}{D} \\
m_r^{Ml} &= \frac{p_r^{ML}}{D}
\end{aligned} \tag{2}$$

where the suffix p_l and p_r denote the left and right tangents.

Next, we note the equation of the tangents below.

Tangents in ML scout:

$$\frac{y-0}{x-(-r_0)} = m^{ML} \tag{3}$$

Tangents in AP scout:

$$\frac{y-r_0}{x-0} = m^{AP} \tag{4}$$

The equation of the ellipse in the two configurations are noted below.

Ellipse in ML scout:

$$\left(\frac{y-y_0}{R_y}\right)^2 + \left(\frac{x-x_0}{R_x}\right)^2 = 1 \tag{5}$$

Ellipse in modified AP scout configuration:

$$\left(\frac{y-(y_0-d)}{R_y}\right)^2 + \left(\frac{x-x_0}{R_x}\right)^2 = 1 \tag{6}$$

Now, the system of equations provided by equations **??** and **??** allow us to solve for the points of intersection of tangents to the ellipse in the ML scout. We apply the following operations on the system of equations:

1. Though the value of $m_M L$ is known, we do not substitute this into the equation at first
2. Substitute the equation for y provided in Eq. **??** into Eq. **??**
3. Step **??** yields a quadratic in x. Since the the system of equation allows only a unique solution for each tangent, we can apply the formula that the discriminant of this quadratic is zero
4. Step **??** yields a quadratic in m. The parameters of the ellipse $\{x_0, y_0, R_x, R_y\}$ are also embedded in this equation
5. Using the above quadratic which is of the form $Am^2 + B^m + C = 0$, we use the formulae for sum of roots and difference of roots

By following the above set of steps for both the ML and AP scouts, we arrive at the following system of equations:

$$\begin{aligned}
\Sigma_1\left(Bx_0^2-1\right)+2Bx_0\left(r_0+d-y_0\right)&=0\\
A\Delta_1^2\left(Bx^2-1\right)-4B\left(A\left(r_0+d-y_0\right)^2+Bx_0^2-1\right)&=0\\
\Sigma_2\left(B\left(x_0+r_0\right)^2-1\right)+2By_0\left(x_0+r_0\right)&=0\\
A\Delta_2^2\left(B\left(x_0+r_0\right)^2-1\right)-4B\left(Ay_0^2+B\left(x_0+r_0\right)^2-1\right)&=0
\end{aligned}\tag{7}$$

where we used the following substitutions to simplify the equations:

$$\begin{aligned}
A&=\frac{1}{R_y^2}\\
B&=\frac{1}{R_x^2}\\
\Sigma_1&=m_l^{AP}+m_r^{AP}\\
\Sigma_2&=m_l^{ML}+m_r^{ML}\\
\Delta_1&=m_l^{AP}-m_r^{AP}\\
\Delta_2&=m_l^{ML}-m_r^{ML}
\end{aligned}\tag{8}$$

Thus we have a system of four equations with four unknowns $\{x_0, y_0, R_x, R_y\}$. This system can be solved with numerical solvers to yield the parameters of the ellipse (i.e. an estimate of the patient body habitus).

3. RESULTS

Here we show experimental proof for the following:

- ***[Completed]***: For Shepp-Logan phantom placed at an arbitrary displacement from iso-center, if ML scout is non-truncated and AP scout in modified configuration is non-truncated, then the four parameters of the ellipse are accurately determined. Example below:
  - Shepp Logan phantom was expressed into a 512×512 image grid. The major and minor axes were measured manually as R_x and R_y pixels. A perturbation from iso-center (x_0, y_0) was introduced. Thus we ran simulations using $\{x_0 = -5, y_0 = -8, R_x = 233, R_y = 177\}$
  - Scout projections were generated using OpenRecon forward projector codes
  - The AP scout was truncated (and ML scout was non-truncated) in the original configuration. By moving the detector down by 200 mm, a non-truncated AP scout was acquired.
  - The edges of the non-truncated scout views were measured and the slope of the tangents were calculated using equations **??** and **??**
  - Finally, the system of equations **??** was solved to determine the unknowns $\{x_0 = -4.89, y_0 = -8.16, R_x = 233, R_y = 173\}$
  - We noted that the calculated values matched the simulation parameters closely
- ***[Completed, need to add description]***: Next, we showed that knowledge of the patient habitus (approximated by an ellipse) led to more accurate interior tomography than existing methods (that do not use knowledge acquired from the scout views)
- ***[To be done]***: Finally, we show the same trend in results for real clinical data for obese patient cases