Virtual Acquisition: Efficient, Accurate and Low-dose kV-Projection based Positioning

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INTRODUCTION

- kV-projection based positioning relies on an assumption that DRR (generated at planning position) and its corresponding kV projection (acquired at setup position) are consistent.
- Paradoxically, the assumption is not valid until the positioning task is accomplished (when setup position is aligned to planning position). During the positioning, inconsistency is always existing. E.g., when setup position is away from the planning one, also towards the detector, the acquired kV projection will be smaller than its DRR counterpart ---- in this case, DRR and kV projection are essentially different, meaning no theoretically accurate matching.
- As a result, in-negligible discrepancy is introduced in the following 2D-3D/6D registration process. Especially when the initial positioning is not accurate, for body setup, or laser-free initial positioning.
- While the above problem can be mitigated by increasing initial setup accuracy, or/and re-acquire kV projections for a refined registration, these approaches increase labor-intensity and setup time. We observed some cases where three re-acquisitions (3 pairs of kV projections) are needed, tripling its imaging dose (measured as 0.63mGy), not mentioning the extra time/efforts spent in re-acquiring and re-registration.

AIM

To understand and solve the inconsistence between DRR and its corresponding kV projection

To enhance the kV-projection based positioning being with better accuracy, higher efficiency and lower-dose.

METHOD

- We have developed a Virtual Acquisition (VA) algorithm.
- In each sub-cycle of VA, instead of physically moving/rotating the objects and re-acquiring kV projections, we reversely apply the registration results to the reference images and regenerate the DRRs. VA converges with consistent DRR and kV pair, and the result of all the sub-cycle are accumulated as the final registration output.

SUMMARY

- VA addresses the inconsistency fundamentally between the pair of DRR and kV projection.
- With VA embedded, kV-projection based positioning truly becomes an efficient, accurate and low-dose image-guided patient setup approach.
- By using this technology, less time/efforts could be spent on manual setup. E.g., with 3D couch, focus can be more on adjusting rotations.
- Laser-free manual setup might be potentially possible for kV-based positioning, given no large rotation exist.

RESULTS :

- **Problem demonstration:** Regarding a dot-structure V, we calculate its DRR P. With offset r and rotation A, we calculate its kV-projections P_1 and P_2, as shown in Figure 1.

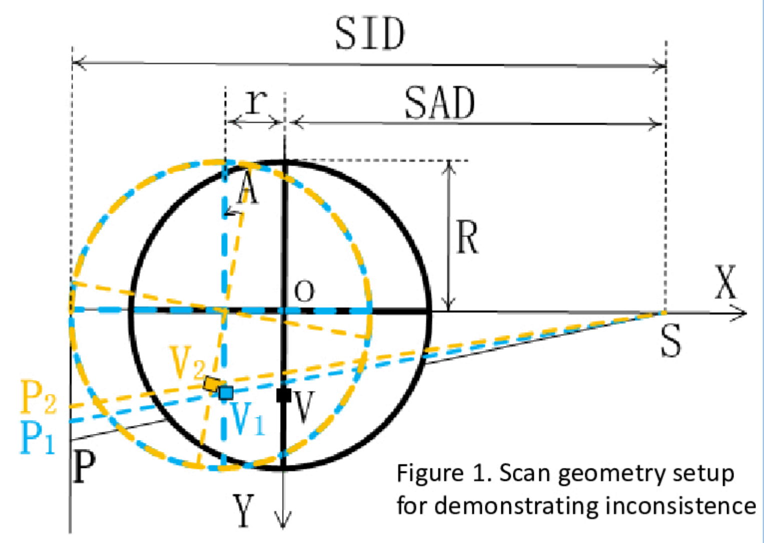

Figure 1. Scan geometry setup for demonstrating inconsistence

- Inconsistence becomes more significant when 1) the distance (R) from region-of-interest (ROI) to ISO is further, and 2) the setup position offset (r) is larger, especially with rotation (A). For a dot-structure at R= 70 or 110mm (FOV of 220mm), r=5 or 10 and A=1 degree (common in IGRT practice), the inconsistence is calculated as 0.52 or 0.82mm when r=5mm, and increases to 1.04 or 1.63mm for larger offset r=10mm, and 1.15 or 1.92mm with rotation (r=10mm, A=1 degree), as shown in Table 1.

Table 1. Inconsistence quantifying. The scan-geometry is shown in Figure 1. Parameters: SID=1500. SAD=1000. All units are in mm if not noted specifically. Row 2-4 list the inconsistence (location difference between DRR and kV projection), where P, P_1 and P_2 are corresponding to DRR, kV projection with offset r and with both offset r and rotation A, respectively

r = 0	$\lvert oV\rvert$	10	30	50	70	90	110	130
r = 5, A=0	$\lvert P_1P\rvert$	0.07	0.22	0.37	0.52	0.67	0.82	0.97
r = 10, A=0		0.15	0.44	0.74	1.04	1.34	1.63	1.93
r = 10, A= 1 deg	$\lvert P_2P\rvert$	0.15	0.46	0.80	1.15	1.52	1.92	2.33
r = 10, A= 2 deg		0.14	0.46	0.83	1.23	1.67	2.15	2.68

- **Performance: VA based 2D-6D vs CBCT based 3D-6D** is tested on CIRS head phantom. The mean/variance of the differences regarding offsets and rotations are {0.30, 0.17, 0.36}/{0.01, 0.01, 0.01} in mm and {0.16, 0.23, 0.17}/{0.02, 0.06, 0.03} in degree. Figure 2 illustrates an example, where large offsets and rotations were given purposely. With VA, DRR and kV projection matches well, and 2D-6D registration yields offsets {-24.2, -3.5, -17.2} in mm and rotation {2.7, 2.6, 0.3} in degree. They are close to the 3D-6D offsets {-24.1, -3.6, -16.7} and rotation {2.8, 2.6, 0.3} in degree

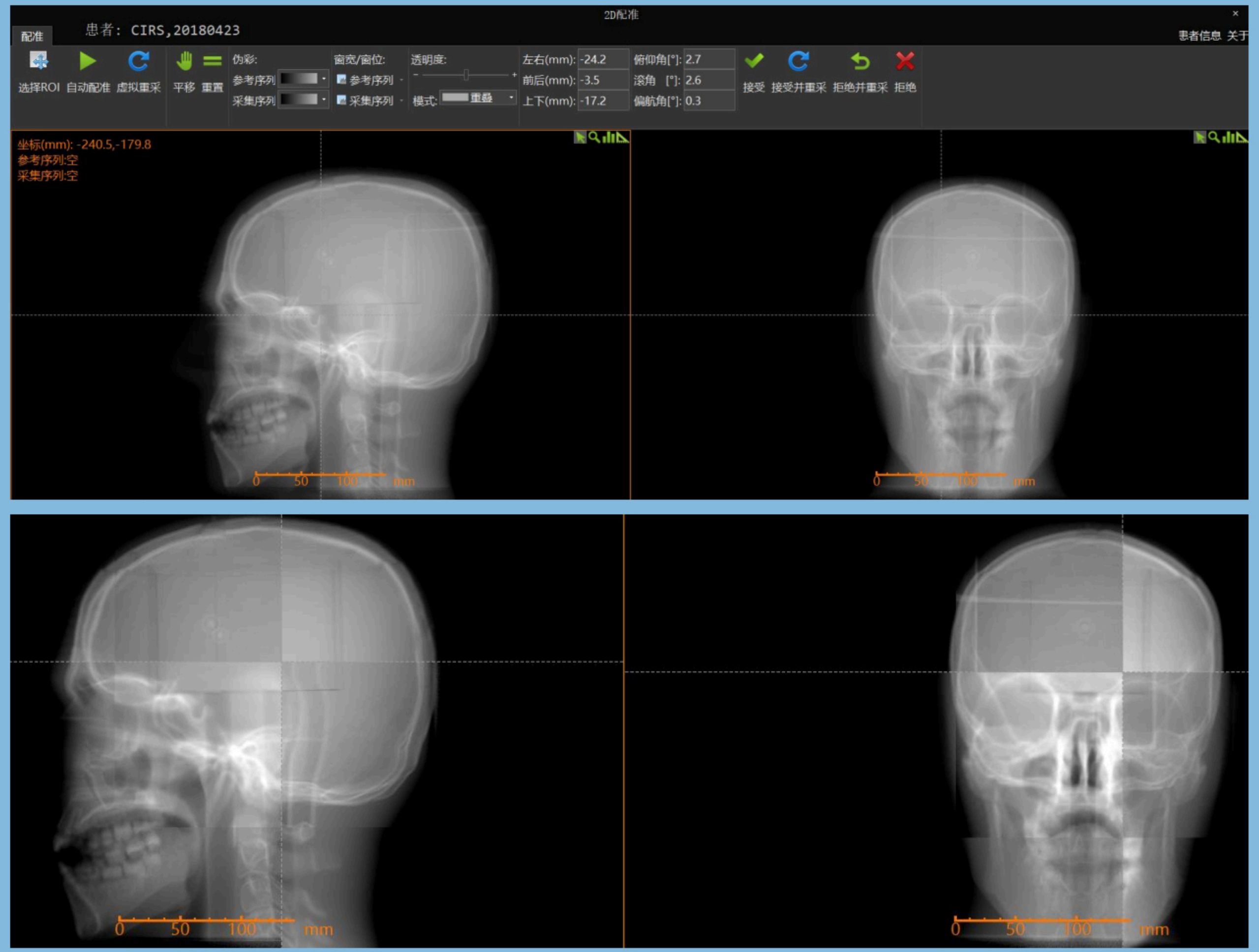

Figure 2. Top row: VA based 2D-6D registration for CIRS phantom. Large offsets/rotations were purposely given. The DRRs and kV projections are displayed with overlapping mode. Bottom row: The same 2D-6D registration results displayed with checkboard mode

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