Reconstruction of intrafractional 3D images from real-time 2D kV radiograph and 4DCT

JongWon Kim, Guang-Pei Chen, An Tai, Sara Lim, Timothy Keiper, X. Allen Li, and Hualiang Zhong
Medical College of Wisconsin, Department of Radiation Oncology, Milwaukee WI, USA

INTRODUCTION/AIM

3D images during treatment delivery can help assess the dosimetric impact of intrafractional motion and enable treatment plan adaptation to account for deviations in the delivered dose. The technique in this study is novel in generating each set of intrafractional 3D images by integrating a respiratory motion model with each real-time kV radiograph at limited angles during treatment instead using whole series of radiograph. The purpose of this study is to develop a method that enables the generation of time-resolved intrafractional 3D images from individual real-time kV radiographs acquired at limited angles during treatment.

METHOD

- 4DCT and intrafraction kV radiographs were collected.
- A MidP-CT was first generated from the planning 4DCT.
- Using DIR, the MidP-CT was registered with each of the 10-phase images of 4DCT.
- The motion state Š of any anatomical structure can be modeled with Š = S + α·Dφ, where S is the reference state (MidP), α is the amplitude, and Dφ represents the output obtained by interpolating the input DVFs in correspondence of phase φ.
- 3D images corresponding to each motion state were used to generate a DRR database.
- Real-time kV radiographs acquired during treatment delivery were compared to the DRR database to determine the α and φ of the motion model which are used to quantify changes in patient anatomy for each radiograph.

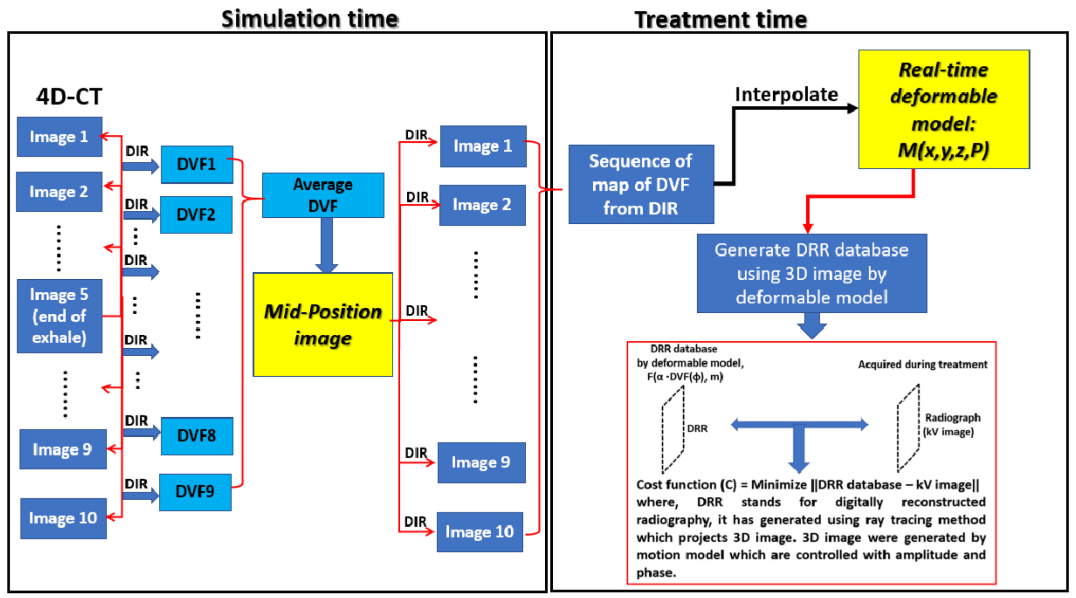

Figure 1. Workflow of developing motion model and generating 3D volumetric images using kV image

RESULTS

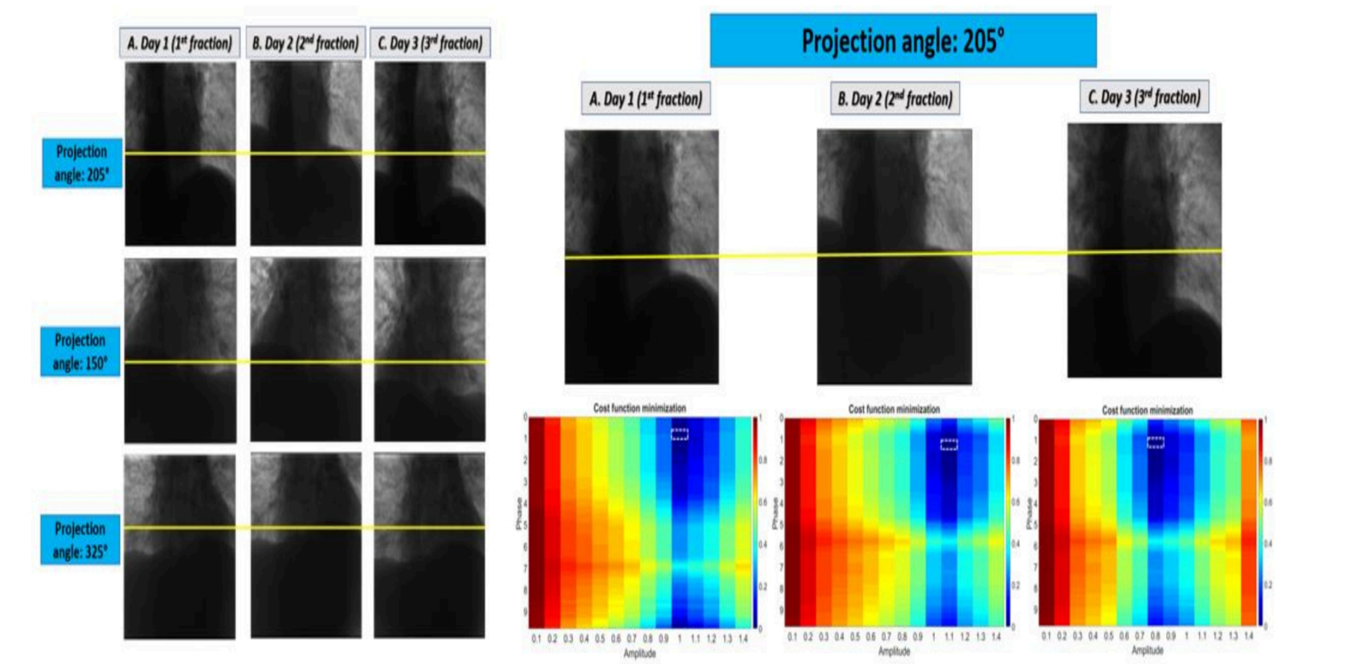

Figure 2. Radiograph images at different projection angles and fractions during treatment. Best matched parameters were determined by comparison between DRR database and radiograph

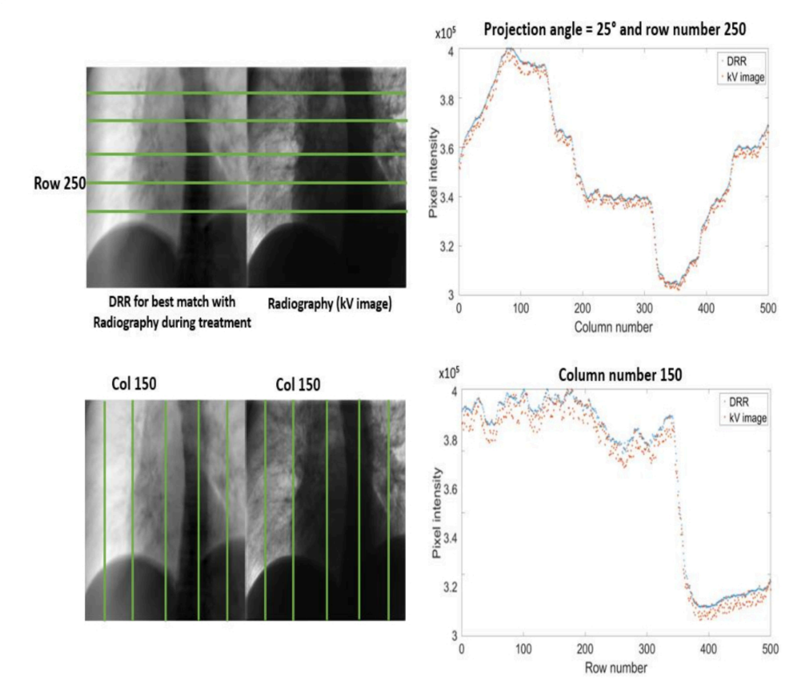

Figure 3. Intensity comparison between radiograph and best matched DRR at projection angle 25 for both horizontal and vertical linescans

Patient 1		Projection Angle				
		25°	150°	205°	325°	Mean±Std (%)
Mean±Std (%)	5 Rows	7.8±4.1	8.1±3.7	8.5±4.4	7.3±5.3	7.9±4.3
	5 Columns	10.7±5.8	11.3±6.8	10.8±5.7	10.1±5.9	10.7±6.0
Patient 2		**Projection Angle**				
		55°	165°	230°	355°	Mean±Std (%)
Mean±Std (%)	5 Rows	6.1±4.4	8.6±5.3	7.2±4.0	6.9±4.3	7.2±4.5
	5 Columns	11.3±5.8	12.5±5.9	10.8±6.3	11.7±6.9	11.6±6.2
Patient 3		**Projection Angle**				
		45°	135°	230°	310°	Mean±Std (%)
Mean±Std (%)	5 Rows	8.8±4.1	7.9±4.4	9.5±4.5	8.6±3.9	8.7±4.2
	5 Columns	13.7±6.8	10.4±5.3	11.2±5.1	10.7±6.6	11.5±5.9

Table 1. Quantification of intensity difference between radiograph and best matched DRR for 4 different projection angles and 3 patients

Target image (warped) – MidP image	Patient 1	Patient 2	Patient 3
AP (mean)	0.72±0.31	0.66±0.34	0.98±0.39
RL (mean)	0.63±0.26	0.59±0.30	0.79±0.24
SI (mean)	1.88±0.92	2.04±0.89	2.33±0.77
3D (mean)	2.11±1.13	2.42±0.92	2.90±0.84

Table 2. Quantification evaluation of DIR for target image using 300 landmarks

- Mean registration errors of 2.1±1.1, 2.4±0.9, and 2.9±0.8 mm in 3 patients (Table 2)
- The percent difference of pixel intensities calculating by computing subtraction between best-matched DRRs and radiographs was 7.7±4.3, 7.2±4.5, 8.7±4.2% along the horizontal lines, and of 10.7±6.0, 11.6±6.2, 11.5±5.9% along the vertical lines
- In the approximate 2.5 mm uncertainty of the motion model, the pixel values are in good agreement between the best-matched DRRs and radiograph.

CONCLUSION

Within the uncertainty of the model, pixel intensities are in good agreement (within 7%) between the best-matched DRRs and radiograph. Intrafractional 3D images can be retrospectively produced from individual 2D images for dose accumulation for adaptive radiotherapy in the presence of inter- and intra-fraction motion for thoracic and abdominal treatments.

CONTACT INFORMATION

JongWon Kim, kjongwon@mcw.edu &
Hualinag Zhaong, hzhong@mcw.edu