Dynamic HU Mapping and Deformable Image Registration Algorithm for Adaptive Treatment Planning and Dose Calculation Using Neural Network

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BACKGROUND

Patients who undergo fractionated radiotherapy (RT) are subjected to day to day anatomical changes, the changes might affect the gross tumour volume (GTV) delineated in the initial planning CT (pCT). Only in case of excessive weight loss, the patient is prescribed to undergo a repeat CT and re-planning procedure to incorporate the observed changes. This results in adding additional cost to the treatment and undocumented imaging dose to the patient.

AIM

To develop an adaptive HU mapping and deformable image registration (DIR) technique which uses programmable neural network to create a new synthetic CT using pre-treatment verification CBCT

METHOD

Prior to perform DIR, the initial pCT was registered with an extended CBCT (eCBCT) i.e., a protocol developed in our previous study for extending the field-of-view of conventional CBCT by acquiring the image through iterative couch shift. After rigid image registration, the Eclipse demons DIR algorithm was used to deform the pCT with respect to eCBCT. The images are then exported to MatLab system for performing adaptive HU mapping. Subsequently, the deformed CT (dCT) and eCBCT are optimally matched using MatLab mean-square rigid registration algorithm. later, the HU values in tissue and bone regions are segmented for dynamic HU correction and composite mapping of eCBCT and dCT using customised neural network, resulting in an optimal synthetic CT incorporating the anatomical changes and HU values of dCT.

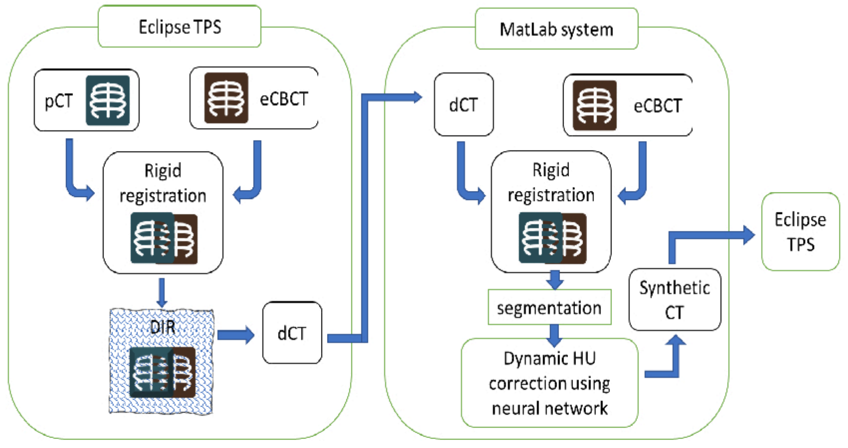

Fig 1. Algorithmic workflow for image processing

RESULTS

The synthetic CTs were compared with the repeat CT (rCT) / HU corrected eCBCT of patients who completed RT . The standard comparison metrics viz, centre of mass shift (CMS) and volumetric dice-similarity coefficient (DSC) were analysed between the registered images. identical re-planning procedure was used for dose comparison and gamma analysis.

DCS and CMS and gamma analysis

The comparison between DCT and eCBCT shows minimal volume change except for the lung contour which alternates in various breathing cycles, this shows the accuracy of the deformable image registration technique and the need for performing DCT/rCT for adaptive RT. Gamma analysis showed 97 to 99 pass percentage when compared to repeat CT calculated dose plan.

HU comparison

The synthetic CT was then compared with the planning CT and repeat CT in various anatomical regions to check the reproducibility of HU values were in agreement with minimal deviation, However the representation of actual anatomy was slightly distorted due to many post processing techniques handled. In the future scope of the study we aim to correct those distortions and perfect the algorithm to standardise synthetic CT as an alternative for repeat CT.

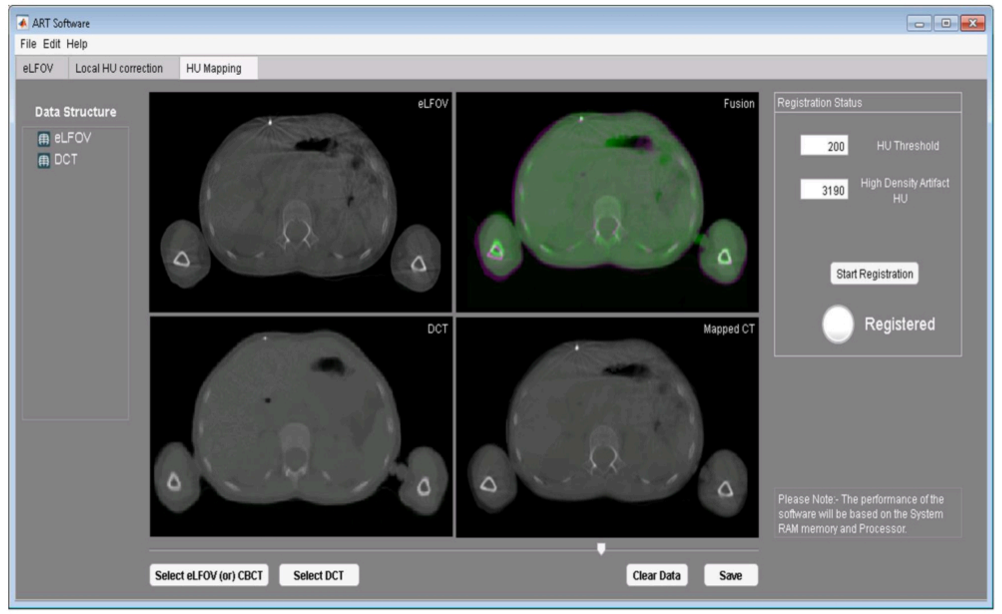

Fig 2. In-House developed HU mapping software

DCT vs eCBCT

Structure ID		Volume cm^3	Volume Change cm^3	Center of Mass Shift x-Direction [cm]	Center of Mass Shift y-Direction [cm]	Center of Mass Shift z-Direction [cm]	Dice Similarity Coefficient
Esophagus	eCBCT	12.8					
	DCT	13.4	0.6	0.05	0.23	-0.73	0.59
Left eye	eCBCT	6.6					
	DCT	7.7	1.1	0.3	-0.13	-0.21	0.74
Right eye	eCBCT	6.5					
	DCT	6.8	0.3	0.29	-0.27	-0.16	0.7
Left optic nerve	eCBCT	0.2					
	DCT	0.1	-0.1	0.16	0.03	-0.05	0.06
Right optic nerve	eCBCT	0.2					
	DCT	0.2	0	0.38	0.11	-0.08	0.01
Optic chiasm	eCBCT	0					
	DCT	1.6	1.6	0	0	0	0
Mandible	eCBCT	59.2					
	DCT	58.7	-0.5	0.01	-0.04	0.08	0.87
Right lung	eCBCT	573.8					
	DCT	549.2	-24.7	-0.14	0.5	-0.28	0.9
Left lung	eCBCT	549.7					
	DCT	440.4	-109.3	-0.02	0.54	0.13	0.85

Table 1: centre of mass shift (CMS) and volumetric dice-similarity coefficient (DSC) comparison between DCT and HU corrected eCBCT

CONCLUSIONS

While preserving soft tissue data during registration and transferring of image voxels, due to minor registration errors, we observed certain air cavities formed in the chest wall region. On further investigation the registration methodology was found to be more efficient when used with neural networking.

Hence, the existing algorithmic workflow was modified to include the dynamic HU mapping based on neural networking Effective implementation of this workflow will eliminate the need for repeat CT (rCT). This will be helpful for economically backward patients who cannot afford weekly interim CTs for conventional ART.

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