Sparse patch-based method applied to MRI-only Radiotherapy Planning

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INTRODUCTION/PURPOSE

- Replacing CT/MRI in radiotherapy chain with MRI-only will:
  - Reduce imprecise target positioning due to CT/MRI fusion;
  - Decrease the workload and associated cost ;
  - Avoid, for the patient, the dose of ionizing radiation due to CT.

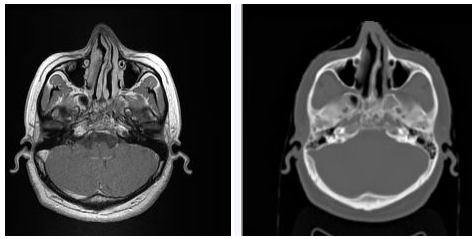

Fig1. MRI and CT slices at the same position

Generate synthetic-CT (sCT) from MRI sequences using “Sparse Patch-Based Method”;

Assess sCT for MRI-only radiation therapy planning and verification.

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METHODS

❑ Dataset Description

- Retrospective study on 12 patients with brain cancer;
- Use of co-registered CT and contrast-enhanced T1-weighted MRI (1.5T GE MRI-simulator, 3D fast spoiled gradient pulse sequence, TR = 8.464ms, TE= 3.248ms);
- Resampling of the scans to $1x1x3mm^3$;
- Exclusion of background from MRI [1] ;
- Mapping of database and target MRI histograms [2].

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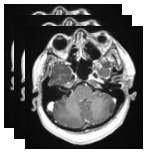
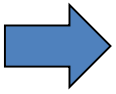
METHODS

❑ Sparse Patch-Based Method - SPBM

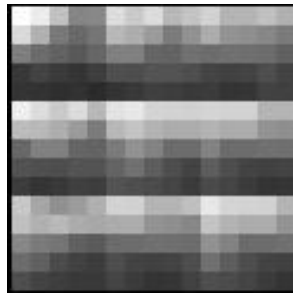


Target MRI

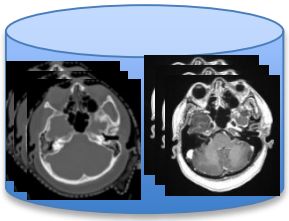


Target MRI patch P_t

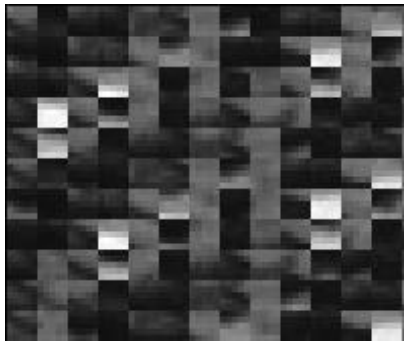
$\forall P_t$



Reconstruction of P_t from a sparse linear combination of the library patches using Elastic Net optimization[3]



Database of linearly co-registered CT/MRI



Library of MRI patches with corresponding CT

Sparse prediction of sCT

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METHODS

❑ Geometric Evaluation Measures

- Mean Absolute Error (MAE) between CT and sCT voxels intensities within head region;
- Dice(DI) for automatically segmented bones.

❑ Radiological Evaluation Measures

- MAE of Water Equivalent Path Length (MAE_{WEPL}) computed for multiple spokes starting from the center of the head towards the upper hemisphere.

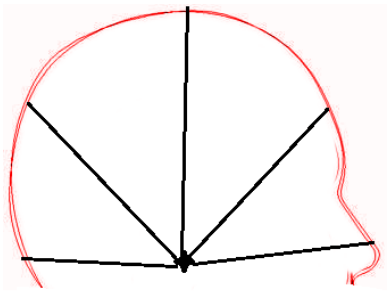

Fig2. WEPL was computed for 1860 spokes towards the upper skull

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METHODS

❑ Dosimetric Evaluation

- Creation of two types of PTV in sCT/CT:
  - PTV1 : heterogeneous region;
  - PTV2 : homogenous region;
- Delineation of OARs in sCT/CT;
- Generation of VMAT plans (6MV, 2Gy in 30 fractions) on sCT and copying them to real CT for comparison;
- Dose calculation with AAA in Eclipse™;
- Computation of Percentage of DVH Metrics Deviations (PDMD) (ICRU Report No. 83, QUANTEC Guidelines).

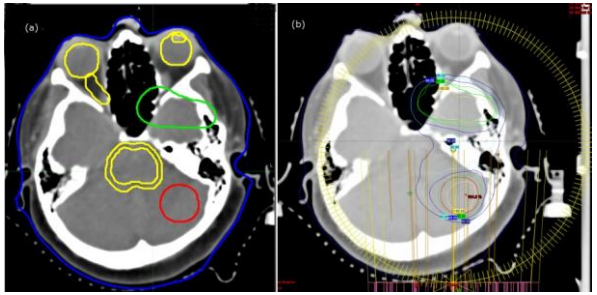

Fig3. (a) contours for PTV1 (green), PTV2 (red) and OARs (yellow) on a real CT transverse slice. (b) Isodoses and VMAT arcs for the same slice.

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RESULTS

- Good visual agreement for sCT/CT and sCT-DRR/CT-DRR pairs:

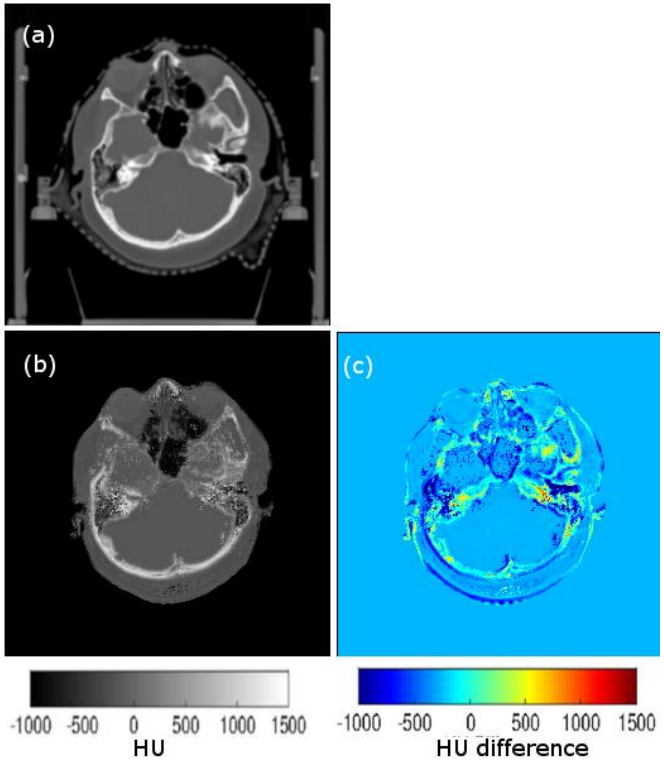

Fig4. (a) Transverse slices of CT,(b) pCT (c) image difference pCT-CT

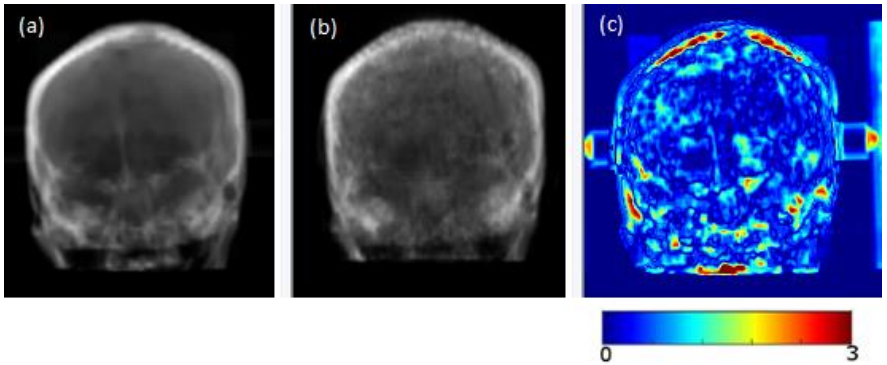

Fig5. (b)Anterior-Posterior DRRs from CT, (b) from sCT, (c) γ (DTA =2mm, ΔI=5%) map with reference CT-based DRR

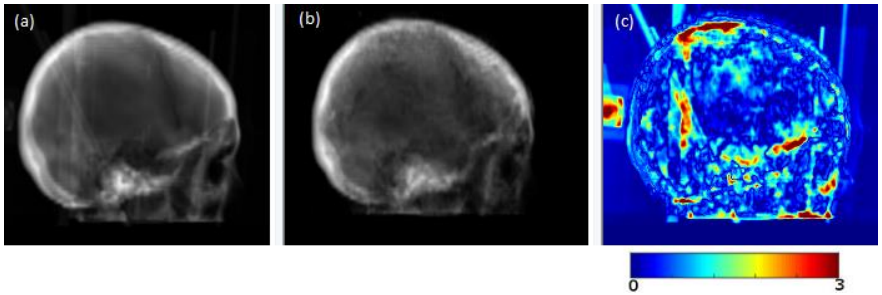

Fig6. (b)Lateral DRRs from CT, (b) from sCT, (c) γ (DTA =2mm, ΔI=5%) map with reference CT-based DRR

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RESULTS

- The mean and standard deviations over 12 patients of MAE, MAE_{WEPL}, DI_{Bone} for SPBM were :

	MAE [HU]	MAE_{WEPL}[mm]	DI_{bone}
SPBM	126.43 ± 13.37	2.08 ± 0.41	0.75 ± 0.02

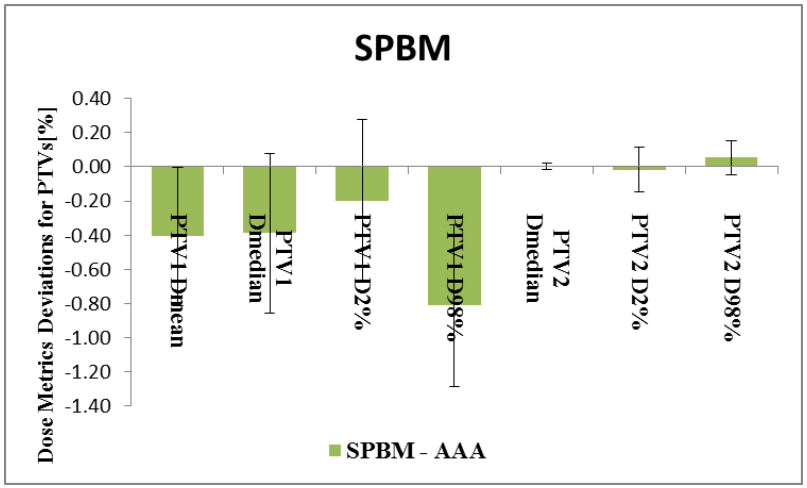

Fig7. Dose metric deviations, for PTVs, using AAA dose calculation. Means and STD are shown for 12 patients.

- Using SPBM, the highest PDMD was:
  - $D_{98\%}$=-0.81±0.47 for PTV1;
  - $D_{98\%}$=0.05±0.1 for PTV2.

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RESULTS

- Using SPBM, absolute average PDMD were <0.4% for OARs;

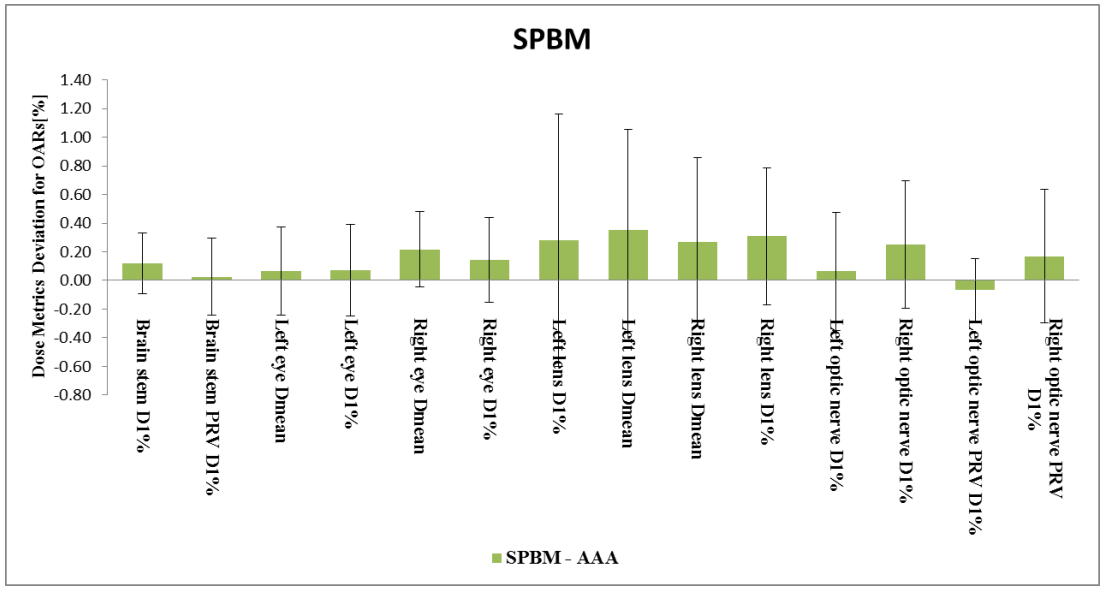

Fig8. Dose metric deviations, for OARs, using AAA dose calculation. Means and STD are shown for 12 patients.

- Good agreement with conventional planning techniques was obtained;
- Synthetic CT, generated by SPBM, could be suitable for MRI-only RT planning.

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CONCLUSION

- We presented novel patch-based approach to create synthetic-CT from standard contrast enhanced T1-weighted MRI;
- The generated synthetic-CT could be suitable for radiotherapy planning and verification in the brain;
- In the future, we will investigate sparse method for PET/MR attenuation correction application.

REFERENCES

1.P. A. Yushkevich, J. Piven, H. C. Hazlett, R. G. Smith, S. Ho, J. C. Gee and G. Gerig, "User-guided 3D active contour segmentation of anatomical structures: Significantly improved efficiency and reliability," Neuroimage, 31(3):1116-28, 2006.

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3.H. Zou and T. Hastie, "Regularization and variable selection via the elastic net," *Journal of the Royal Statistical Society: Series B (Statistical Methodology),* vol. 67, no. 2, pp. 301-320, 2005.