Automatic IMRT planning via Static Field Fluence Prediction (AIP-SFFP): A Novel Local Attention Deep-Learning Design for Head-and-Neck IMRT Application

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME (GMT-4)

Introduction

This study proposed a novel local attention Deep Learning (DL) design for Automatic-IMRT-Planning-via-Static-Field-Fluence-Prediction (AIP-SFFP) for Head-and-Neck (H&N) application. Our earlier work (Li et al, MedPhys 2019) had successfully demonstrated AIP-SFFP for prostate application. However, in H&N cases, the patient anatomy is more complex and has more inter-patient variations than in prostate cases. Therefore, a local attention design is employed to improve the prediction outcome. Results showed that this novel AIP-SFFP algorithm achieved clinically acceptable dosimetric results in HN IMRT application with promising feasibility of clinical application.

Methods

This study features two innovations:

1) A novel DL network, PyraNet. PyraNet employs 18 classic ResNet blocks in Pyramid-like concatenations. Each ResNet block contain 3 cascaded 2D convolutional layers, and the first layer is added to the third layer. The filter number in the second layer is 4 times of that in the first and the third layers. The filter numbers start from 16 and cumulates to 128 in the concatenations. All convolutional layers have a filter size of 3×3 and are followed by an Exponential linear unit activation layer.

2) Local attention design. As shown in Figure 1, the fluence map pixel value is independently predicted from a series of small patch 2D projections. These 2D projections are restricted to a 13×13 pixels field-of-view. Such design aims to overcome the loss of fluence gradients while focusing on local anatomical features, and the synthesized fluence maps may hence reserve more high frequency details.

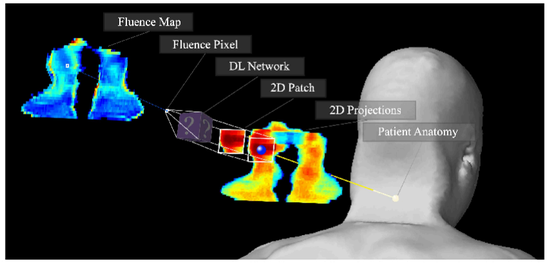

Figure 1. Illustration of the data structure in this study.

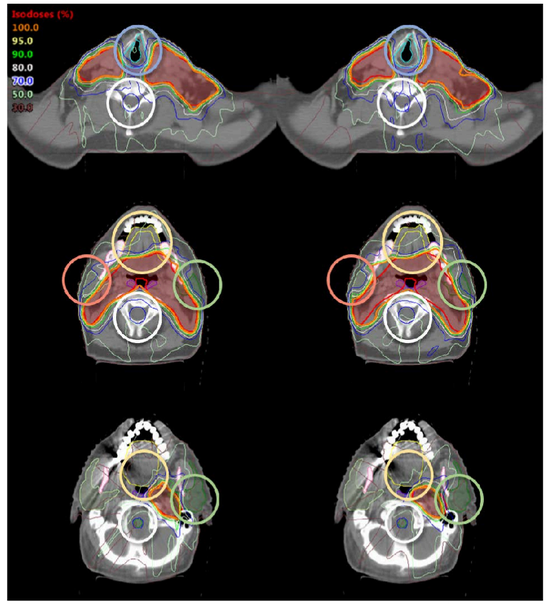

Figure 2. Dose distribution comparison between the research plan (left column) and the AIP-SFFP plan (right column) of a test case.

*Table 1. Comparison of dose statistic (median of 16 cases). * statistical significance.*

	Research plans	AIP-SFFP plans
Brainstem $D_{0.1cc}$ (Gy)	15.5±2.7	15.3±2.8
Cord+5mm $D_{0.1cc}$ (Gy)	25.8±1.9	28.8±2.0
Parotid Left D_{mean} (Gy)	23.1±2.0	23.9±3.1
Parotid Left $V_{30\%}$ (cc)	64.3±6.9	69.1±12.1
Parotid Right D_{mean} (Gy)	23.9±2.3	23.8±3.8
Parotid Right $V_{30\%}$ (cc)	68.6±11.1	69.7±12.7
Oral Cavity D_{mean} (Gy)	23.9±4.3	25.2±6.5
Larynx D_{mean} (Gy)	22.7±4.8	23.8±5.6
Pharynx D_{mean} (Gy)	34.7±2.5	36.7±2.7
BODY D_{2cc} (Gy)	109.0±0.9	130.1±4.3
Total MU	1917.5±203.7	1810.1±205.1

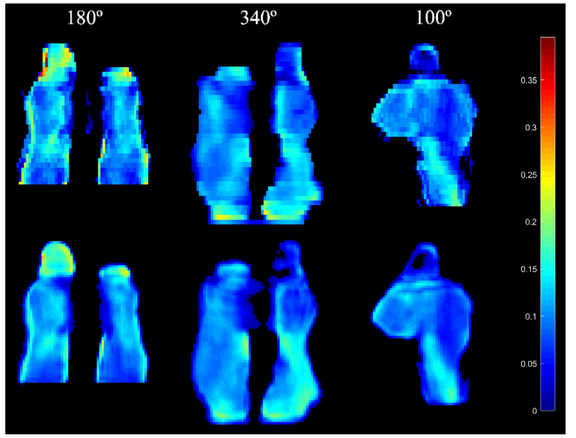

Figure 3. Fluence map comparison.

Results

Figure 3 shows the fluence map comparison of a test case. The fluence maps of these two plans are very similar in terms of shape and intensity. Figure 2 shows the dose distribution comparison of the same test case. The orange isodose line of 100% prescription shows good agreement with the PTV in red. Dose gradient in these two plans is comparable in cord+5mm (white circles), larynx (blue circles), oral cavity (yellow circles), left parotid (red circles), and right parotid (green circles).

Table 1 shows the dosimetric statistics of all 15 test cases. Dosimetric outcomes of all OARs are very similar between the research plans and the AIP-SFFP plans. Total MU is also very close. The AIP-SFFP plans still have a very high maximum dose. But these results fully demonstrated the feasibility of the proposed algorithm for further research and potential clinical application.

Conclusion

This novel AIP-SFFP with local-attention design was successfully demonstrated for H&N IMRT application. Future developments make it promising for future clinical applications.