Toward real-time MR-guided adaptive radiotherapy planning using a deep convolutional conditional generative adversarial network

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AIM

To develop a fast radiotherapy planning technique capable of updating radiotherapy treatment plans on the MR-Linac in real-time.

INTRODUCTION

Recently available MRI guidance with the MR-Linac provides real-time anatomical information and allows for treatment plans to be updated based on changing anatomy. This has the potential to address intra-fractional anatomical changes that may not be adequately accounted for with available motion management techniques. There has been successful development of dose prediction models based on anatomy, but translating a 3D dose prediction to individual field segments and ultimately to multi-leaf collimator positions is necessary to define a deliverable plan. We investigate a deep learning approach to convert a dose map to a deliverable plan.

METHOD

- The proposed deep learning approach to automated step-and-shoot planning consists of two steps. First, predict an ideal dose distribution based on segmented anatomy. Second, the dose map of each beam is segmented into individual aperture shapes. Each step is carried out independent of another. The focus of this study is on step (2).
- 28 adaptive daily plans (18 beams each) for a brain cancer patient treated on MR-Linac (Unity, Elekta) were collected
- Dose distributions of individual beams are rotated towards the beam's eye view and summed, then paired with ground truth apertures for supervised learning
- Data augmentation used to increase training dataset to 13,608
- Knowledge of previous plans was used to guide segmentation
- Trained for 100 epochs, batch size = 32, generator learning rate = 0.0001, discriminator learning rate = 0.0004, binary cross entropy loss used in both generator and discriminator

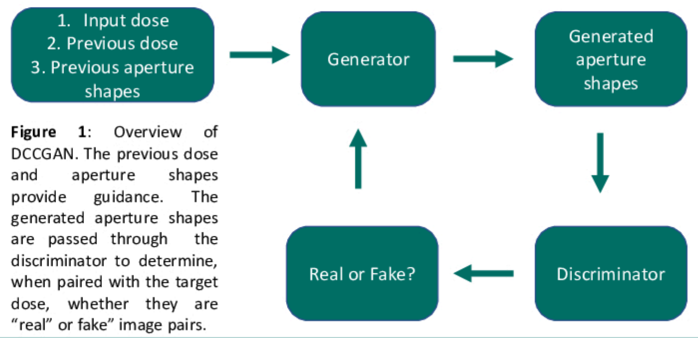
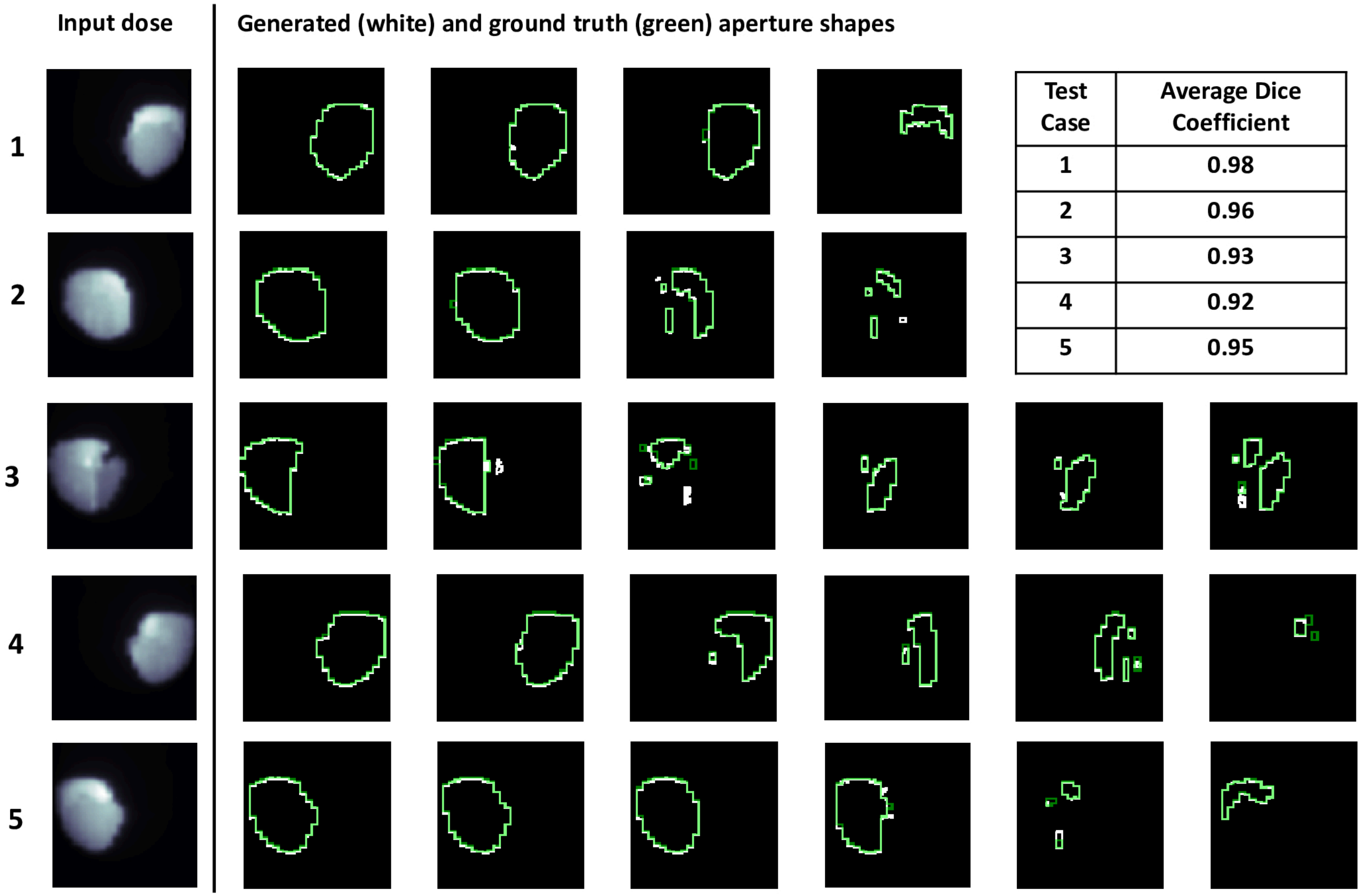


Figure 1: Overview of DCCGAN. The previous dose and aperture shapes provide guidance. The generated aperture shapes are passed through the discriminator to determine, when paired with the target dose, whether they are "real" or fake" image pairs.

RESULTS

The model was tested on data not included during the training phase, but from the same patient. Results for 5 test cases are shown below. The input dose was segmented into 4 (test cases 1-2) or 6 apertures (test cases 3-5).



Test Case	Average Dice Coefficient
1	0.98
2	0.96
3	0.93
4	0.92
5	0.95

Figure 2: Example test data. The left-most column is the input dose that we want to segment. Columns 2-7 are show ground truth aperture shapes in green and generated aperture shapes in white.

CONCLUSIONS

- The proposed deep learning approach to planning has potential for rapid replanning. Dice > 0.92 was obtained for 5 test cases in only a few seconds.
- The input dose map is highly correlated with the sum of the ground truth aperture shapes, so we view this as an overlapping segmentation problem where the sum of the aperture shapes is an image translation of the input dose.
- Paired dose and aperture shapes from a previous plan provide valuable guidance at the input to the network.
- Generation of a fluence map is not required.
- Results for the single adapt to position patient are promising, but we need to explore adapt to shape plans where the change in aperture shape is more dramatic.
- Furthermore, the monitor unit weights were not included in the current model and must be addressed in the future.

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