A Depthwise Separable Convolution Neural Network for Survival Prediction of Head & Neck Cancer

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INTRODUCTION

Deep-learning based radiomics has been drawing increasing attention in the application of cancer diagnosis, tumor classification and survival prediction. While traditional convolution neural networks (CNN) contain millions of parameters, which can be computationally expensive and easily overfit on limited input data, the Depthwise separable convolutions (DSC), first developed in Xception in 2017, significantly reduce parameter count with minor reduction in accuracy, which makes it a promising architecture for deep-learning-based radiomics study.

AIM

To evaluate the performance of a novel deep learning radiomics model in predicting the short-term and long-term survival probability for patients with Head & Neck cancer.

DATA PREPARATION

- A cohort of 466 patients with Stage I to IV Head & Neck squamous cell carcinoma (HNSCC) were selected.
- Original CT and pre-segmented GTV were first resampled to the resolution of 1×1×3 mm^3 and the central 100×100 pixels were cropped.
- Prediction endpoints included 2-year survival, 5-year survival and locoregional recurrence (LR).

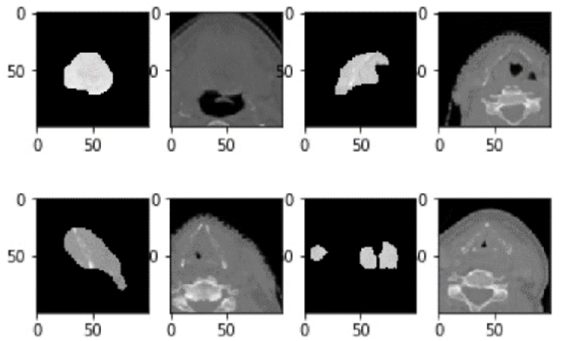


Figure 1. Sample input slices (2×100×100 voxels) with original CT and pre-segmented GTV

Deep Learning Radiomics Modeling

- original CT and pre-segmented GTV were then concatenated in the channel dimension as the input., the seven-layer CNN (Figure 1) took 2×100×100 inputs and generate a binary decision.

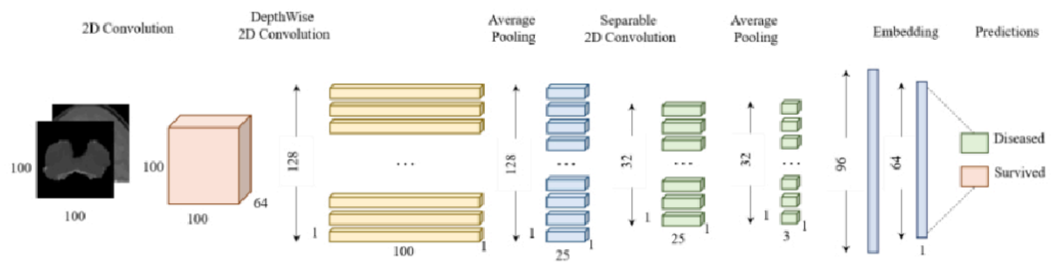


Figure 2. DSC network architecture.

Handcrafted Radiomics Modeling

- For comparison, a random forest (RF) classifier was built using the top 13 features selected from 1189 handcrafted features.

Model evaluation

- For DSC model, take the average score from top ten slices with maximum tumor volumes for each patient .
- The area under receiver operator characteristic curve (AUC) for each endpoint was calculated. Kaplan-Meier curves were calculated for high and low mortality risk groups with an optimal score stratification.

RESULTS

- The proposed CNN architecture, developed in TensorFlow framework was built based on depthwise and separable convolutions with only 58K parameters.
- The proposed CNN model achieved AUC of 0.762 [0.699-0.854, 95% CI], 0.659 [0.593-0.741, 95% CI] and 0.674 [0.580-0.731, 95% CI] for 2-year survival, 5 -year survival, LR prediction in the test set
- While the RF classifier based on handcrafted radiomics features achieved AUC of 0.818[0.703-0.887, 95% CI], 0.653 [0.654-0.813, 95% CI], 0.653 [0.551-0.742, 95% CI].

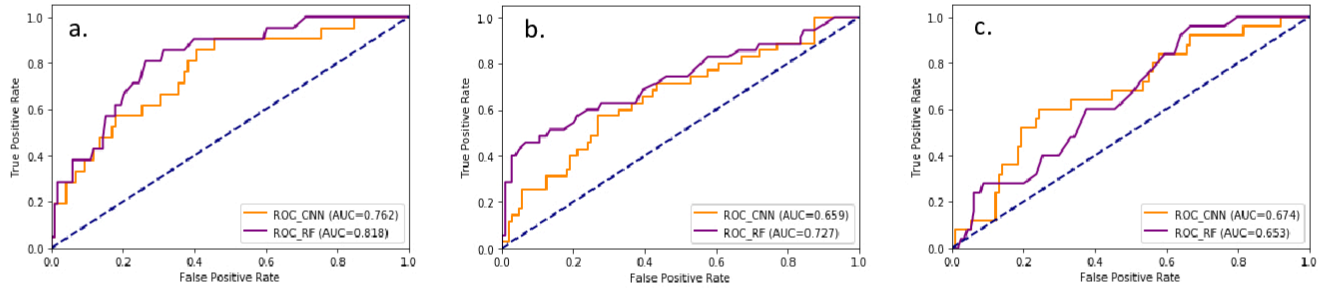
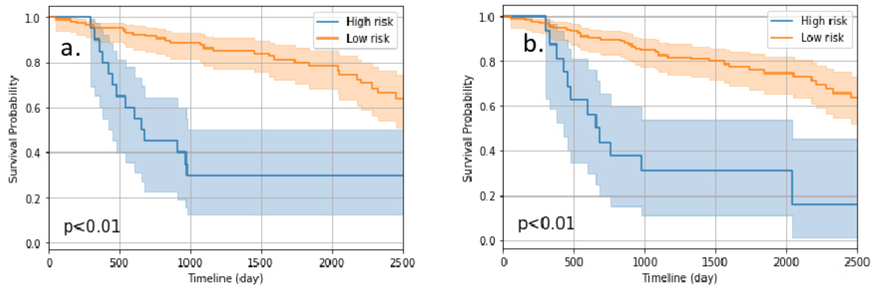


Figure 3. ROC curves of CNN and RF models on testing set (a) endpoint: 2-year survival; (b) endpoint: 5-year survival; (c) endpoint: locoregional recurrence



- Both models were able to stratify patients into a high and low modality risk group in the test set, with a log-rank test p value of 0.0013 (DSC model) and 0.0009 (RF model).

Figure 4. Kaplan Meier curves of high risk/low risk modality groups with an optimal score stratification: (a) CNN model; (b) RF model

CONCLUSIONS

- A training-from-scratch DSC network shows potential in improving the performance of survival prediction using a relatively small training dataset.
- The DSC network model may be potentially beneficial when we are trying to build a complicated radiomics model by adding more convolution layers, or training a three-dimensional CNN model from scratch, instead of applying standard CNN models pretrained on general images.

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