A Normalized Fully Convolutional Approach to Head and Neck Cancer Outcome Prediction

William Le, Francisco Perdigon Romero and Samuel Kadoury from MediCAL lab, CRCHUM Canada Research Chair in Medical Imaging and Assisted Interventions
Treatment context and medical imaging data

Diagnosis
FDG PET-CT

Planning
Planning CT

Treatment
(Chemo-)Radiotherapy

Follow-up
43 months (6-112)

Preprocessing
- 3D → 2d using max GTV area
- Isotropic resampling to 1×1 mm
- Resizing to 128×128
- Normalizing PET to SUV

Data Augmentation (x20)
- Flip 50% probability
- Shift up to 40%
- Rotate up to 20 degrees

Deep Convolutional Neural Network

298 H&N cancer patients

Proposed model


Training and Evaluation

Characteristics

- SeLU activation as regularizer/normalization
- Residual connections to improve convergence rate
- Aggregated convolutions for model capacity regularization
- FCN as a target-oriented image-to-image domain translation or image normalizer

Implementation

- PyTorch using GeForce RTX 2080 Ti
- Categorical cross-entropy loss
- 1:8 resampling to combat data imbalance
- Adam optimizer: 0.0006 lr
- Batch size: 8
- Dataset augmented 20 times
- Total epochs: 100 (1 hour)

Alive / Deceased

CHUS: 83:18
HGJ: 77:14
CHUM: 60:5
HMR: 22:19

Training Validation
197 samples (5:1)

Test
101 samples

# Survival binary classification prediction results

<table>
<thead>
<tr>
<th>Model</th>
<th>PET AUC (Spec, Sens)</th>
<th>CT AUC (Spec, Sens)</th>
<th>Masked CT AUC (Spec, Sens)</th>
<th>PET-CT AUC (Spec, Sens)</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNN¹</td>
<td>59% (90%, 29%)</td>
<td>57% (37%, 77%)</td>
<td>67% (82%, 52%)</td>
<td>65% (99%, 30%)</td>
<td>930,146</td>
</tr>
<tr>
<td>FCN+CNN</td>
<td>59% (41%, 77%)</td>
<td>65% (51%, 79%)</td>
<td>63% (35%, 90%)</td>
<td>70% (69%, 71%)</td>
<td>1,321,682</td>
</tr>
<tr>
<td>AggResCNN</td>
<td>50% (100%, 0%)</td>
<td>65% (54%, 76%)</td>
<td>69% (51%, 87%)</td>
<td>74% (66%, 82%)</td>
<td>291,874</td>
</tr>
<tr>
<td>FCN+AggResCNN (ours)</td>
<td>57% (21%, 94%)</td>
<td>70% (46%, 94%)</td>
<td>67% (52%, 82%)</td>
<td>76% (61%, 91%)</td>
<td>683,650</td>
</tr>
</tbody>
</table>

Conclusion

1. Our proposed CNN model improves over the state-of-the-art for head and neck cancer survival outcome prediction (76% > 65%).
2. Incorporating PET imaging information improves model performance.
3. Our proposed architectural change (FCN, aggregated residual connections) benefit model performance without incurring a larger model complexity cost.
4. The addition of the FCN improves performance when coupled with more complex input features (CT, PET-CT).