RSNA 2022 Cervical Spine Fracture Detection

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1. Introduction

Background

The cervical spine is made up of seven cervical vertebrae, labeled C1 through C7，the Cervical Spine Fracture which is also called neck broken, is a fracture of the seven cervical vertebrae. According to some researches, there are Over 1.5 million spine fractures occur annually in the United States and greater than 3 million patients being evaluated for cervical spine injury in the North America, and this huge number is still rising now. Since many patients with such cervical spine fracture are the elderly, and such group of people can often have a lot of underlying diseases like superimposed degenerative disease and osteoporosis, it can be more difficult for experts to detect the fracture on imaging. On the other hand, this detection on CTs are facing a strain on workforce due to the increasing retirement of the radiologists and a lag in recruitment for new radiologists. Above all, it is increasingly urgent to use artificial intelligence instead of human being to complete such a time-consuming process--- Cervical Spine Fracture Detection.

Societal significance

The use of artificial intelligence to detect fractures in the cervical vertebrae instead of specialists improves the efficiency of detection and avoids delays in diagnosis due to lack of manpower, which can lead to very serious consequences, like catastrophic decline in neurologic function, paralysis and even mortality.

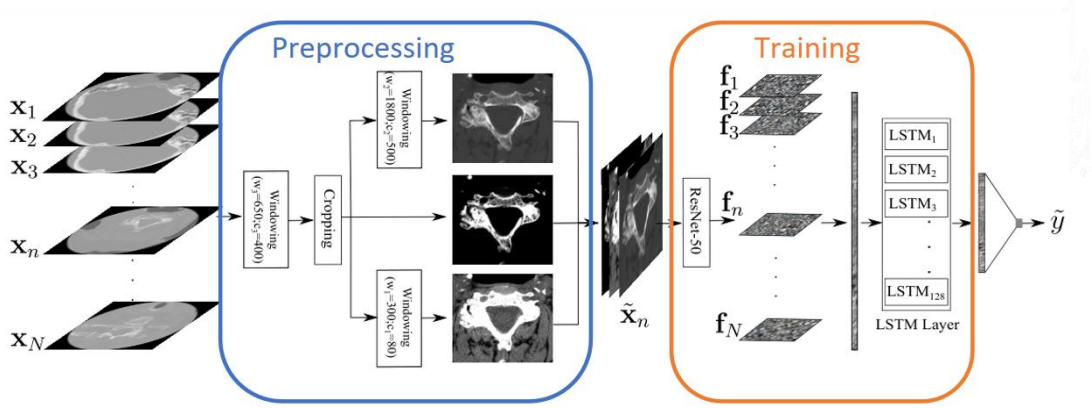
What does this topic cover?

This project aimed to develop machine learning models that match the radiologists' performance in detecting and localizing fractures to the seven vertebrae that comprise the cervical spine on CTs. We need to create a machine learning model and train it to get a satisfied accuracy on identifying the CTs as positive(has a fracture) or negative(no fracture). This project is a competition on Kaggle, Kaggle provides a ground truth dataset which includes approximately 3,000 CT studies from twelve sites on six continents and spine radiologists from ASNR and ASSR provided expert image annotation for these studies to indicate the presence, vertebral level and location of any cervical fractures.

2. The process of detection

In this part, we read Hojjat Salehinejad's paper--”Deep sequential learning for cervical spine fracture detection on computed tomography imaging” and studied the process of constructing and training the model for detection in his article.

In his methods, the model architecture contains two part: the preprocessing part for the imaging data and the training part.



The preprocessing part

During this part, each CT image is duplicated to a set of three images. Each image is chosen from a different window width setting to better represent the soft tissue or the bone fractures. Later on, the images are cropped and centered to the middle of spine bones. All of the processed images are resized to a resolution of 384x384.

The training part

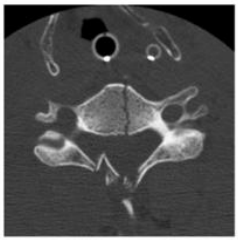
Later on, during the training part, the Resnet-50 is used as the network backbone to extract the feature maps. The feature maps are fed into a BLSTM(Bidirectional Network of LSTM) to generate the fracture labels for the image.

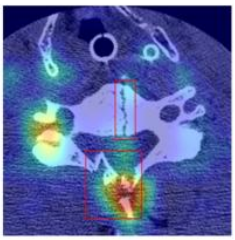
After these steps, the model can detect the CTs as positive or negative.

Results

For the balanced dataset(contains 2,909 positive images and 2909 negative images), the accuracy of detection is about 71.06%. However, for the imbalanced dataset(contains 2,909 positive images and 164,349 negative images), the accuracy is higher, that's about 79.18%. Such higher accuracy for imbalance datasets is mainly due to the bias of the dataset toward negative cases.

And here is a heatmap example below.The heatmap is from the last layer of ResNet-50, which shows the network is able to capture the fractures with a high false positive rate. A false positive image can generate a false positive case, which can dramatically decrease the model performance.





(c) Axial image with two fractures. (d) Heatmap of (c).

3. Other open source research

An FDA-approved CNN developed by Aidoc for cervical spine fracture detection on CT

This model has two stages, the region proposal stage and the false-positive reduction stage, the first stage is a 3D convolutional deep neural network which is made up of many convolutional layers and a pooling layer for reducing the dimension of the output. During the first stage, the dataset do not need to be preprocessed, the region proposals are directly extracted from the 3D segmentation maps and passed to the second stage as input. And during the second stage, 2 sets of features are extracted from each region and after being fused, it can classify each region as positive or negative.

Using AI to detect the cervical spine fracture is still a difficult task and many trouble to figure out, during this project we mainly researched on those two models, and learned a lot about machine learning and fracture detection.

4. Reference

[1] H. Salehinejad et al., "Deep Sequential Learning For Cervical Spine Fracture Detection On Computed Tomography Imaging," 2021 IEEE 18th International Symposium on Biomedical Imaging (ISBI), 2021, pp. 1911-1914, doi: 10.1109/ISBI48211.2021.9434126.

[2] Kalmet, P. H. S., Sanduleanu, S., Primakov, S., Wu, G., Jochems, A., Refaee, T., … Poeze, M. (2020). Deep learning in fracture detection: a narrative review. Acta Orthopaedica, 1–6. doi:10.1080/17453674.2019.1711

[3] Small JE, Osler P, Paul AB, Kunst M. CT Cervical Spine Fracture Detection Using a Convolutional Neural Network. AJNR Am J Neuroradiol. 2021;42(7):1341-1347. doi:10.3174/ajnr.A7094

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