

MRI Tumor Segmentation & Survival Prediction of Brain Metastases Patients

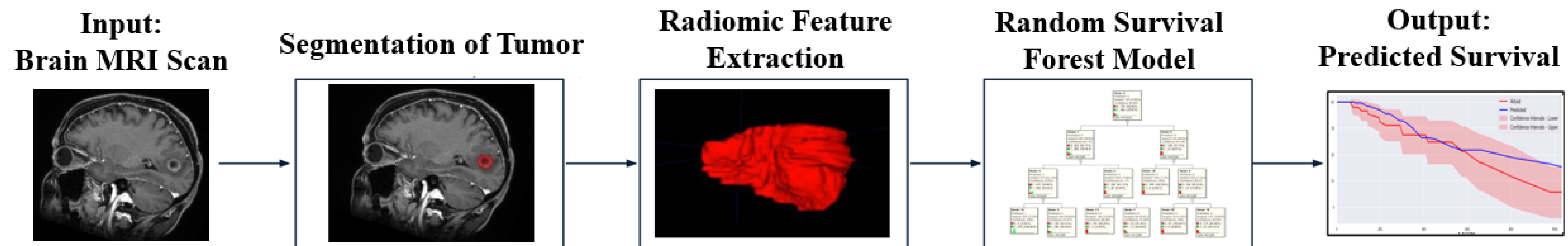
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INTRODUCTION

Brain metastases occur when cancer cells from a primary tumour spread to the brain and form secondary tumors. These occur in 10 to 30 percent of cancer patients and severely impact the prognosis as the median survival time after diagnosis is only 6 months.

Physicians are currently required to identify and segment each tumor by hand. An automated process could reduce time and cost, increase accuracy, and eliminate human error. Furthermore, current brain metastasis survival predictions are inaccurate and lack consistency [1]. As such, the development of a segmentation and survival prediction model with high accuracy could significantly improve treatment success and quality of life for patients.



METHODOLOGY

- Our data consist of 191 MRIs of patients diagnosed with Brain Metastases including the segmentation of tumors drawn by physicians, survival data, and clinical variables.
- Series of machine learning & deep learning models combined to form a pipeline (Figure 1).
- Input of pipeline is a brain MRI, output is a 3D tumour segmentation and survival prediction in days.
- Deep learning nnU-Net is trained using the physician segmented tumors in the data. The model can then perform segmentation on new data.
- Radiomic features are extracted from the segmentation and combined with survival data and clinical variables.
- A Random Survival Forest model is trained to predict survival of patients using this data. This model can now predict survival using only radiomic data and clinical variables.

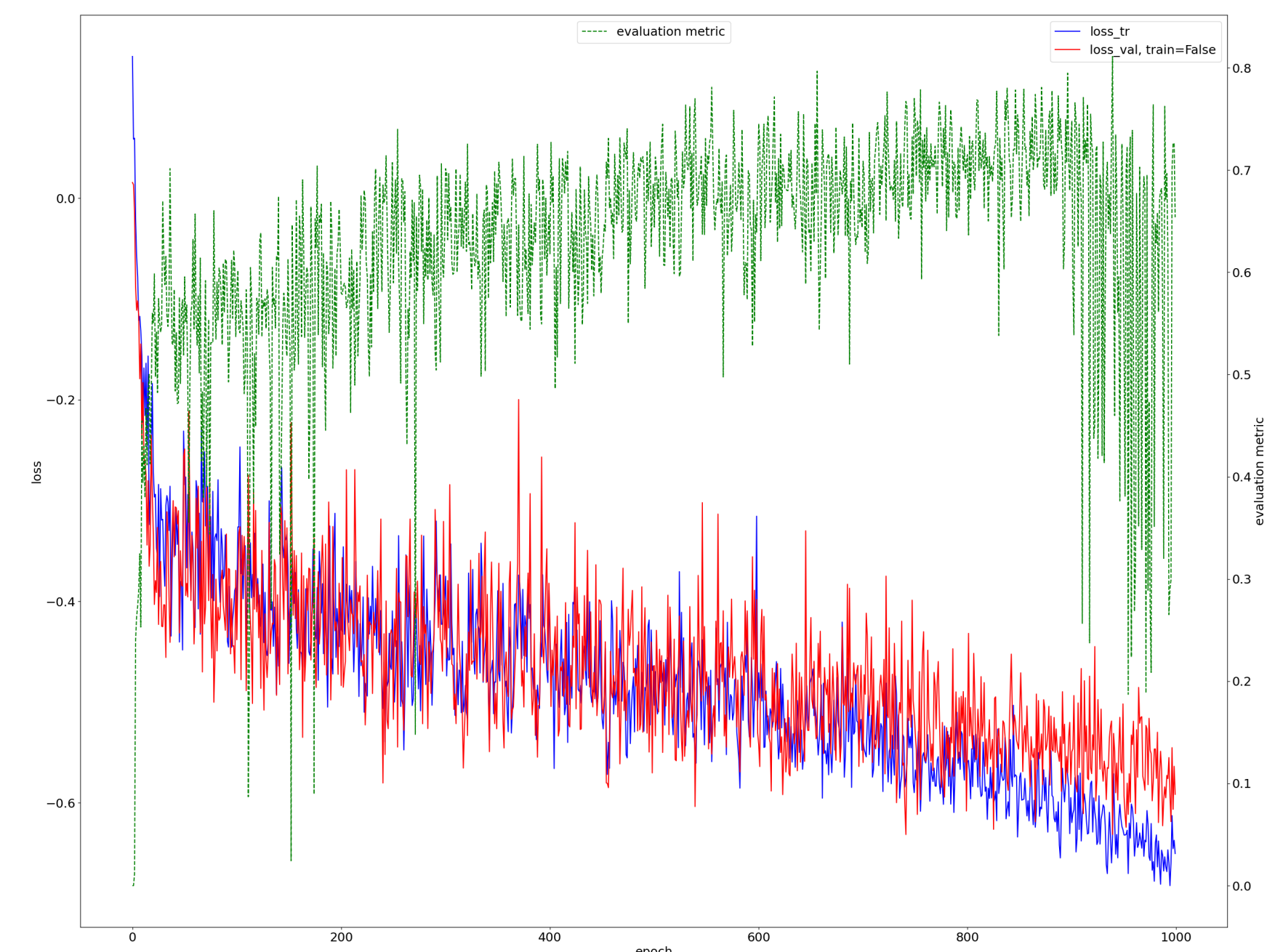


Figure 3 (above): The progression of the model through around 1000 epochs for one cross-validation fold. DICE score (evaluation metric) in green, loss in red. Epochs along the x-axis, loss on the left y-axis, DICE value on the right y-axis.

RESULTS

- Highest scoring segmentation model yields a mean DICE score of 0.71, overlap of the true tumor segmentations and the predicted one.
- Many of the individual predictions have a score above 0.90 (Figure 2), meaning the model is performing very well on select cases.
- Radiomic features are extracted, consisting of statistical and numerical analysis of the tumor. The features, combined with the survival outcome data of each patient can be used to train a Random Survival Forest model to predict how long a patient will survive.
- Patient survival is predicted with a Concordance Index of up to 0.74 and an Integrated Brier Score as low as 0.17. These scores show that a strong prediction signal is established, and that predictions are not random.

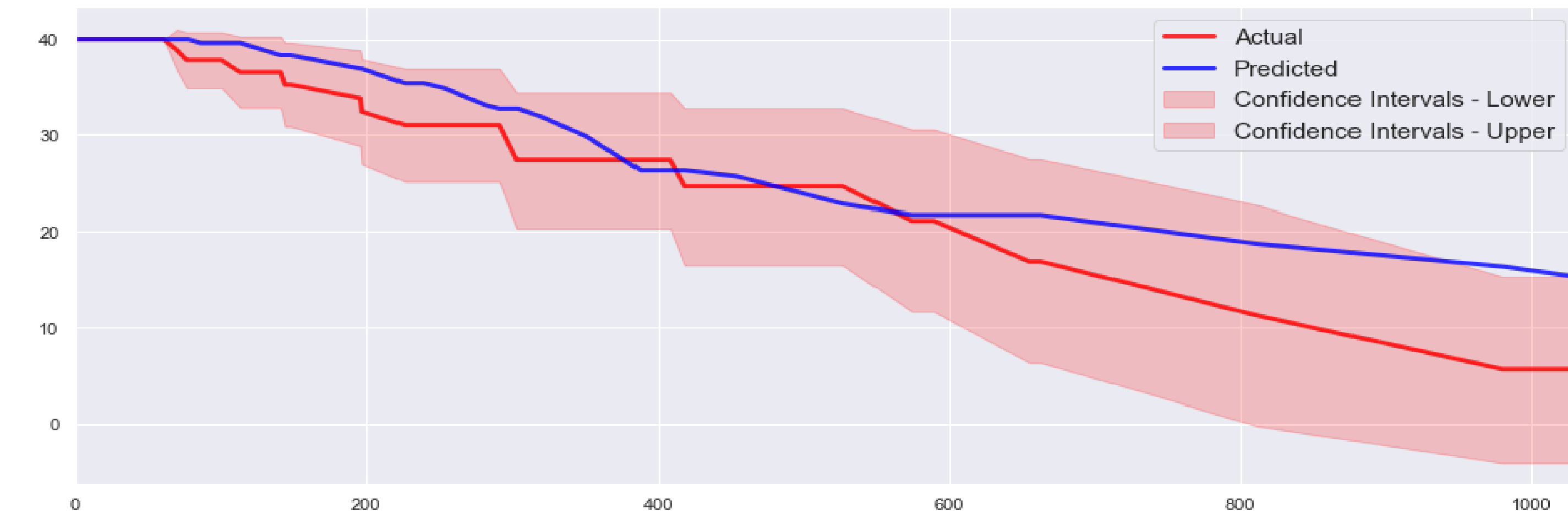


Figure 4: Random survival forest model, actual (red) and predicted survival (blue) plot. Horizontal axis survival in days, vertical axis number of patients

CONCLUSIONS AND RECOMMENDATIONS

For the segmentation, the next step is to determine why the model accurately segments certain test cases but fails to do so on other cases. Further data analysis will be made to observe whether features such as tumor dimensions, number of tumors, and voxel size are correlated with the model's accuracy. The model can then be optimized.

As for the survival analysis, there are two possibilities for improvement. The first is to obtain more data, as this would allow the team to verify the limitations the model may have. Given the timeline of this project, however, this is not an option. The second possibility, which the team will focus on, is to test different radiomic feature extraction methods, and optimize the feature selection process and preprocessing.

The final steps for the project will be to integrate the pipeline into one piece of software with a graphical user interface to allow for facilitated presentations, along with ability to load in scans to segment tumors and make conclusions on the resulting data.

REFERENCES

- [1] D. Kondziolka, "The accuracy of predicting survival in individual patients with cancer," *Departments of Neurosurgery and Radiation Oncology, NYU Langone Medical Center*, 2014.
- [2] Fabian Isensee et al., "nnU-Net: Self-adapting Framework for U-Net-Based Medical Image Segmentation," 2018.

