Data Intensive Engineering Course

TOPIC #

Title: XRAI Pipeline – The creation of a conditionally adaptive loss function for use in medical segmentation tasks

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Background:
The application of artificial intelligence (AI) and deep learning (DL) methods has become a revelation in the high-risk and high-stakes world of medical applications. There is an increasing interest in the exploration of electronic health records (EHR), such as medical images, to identify disease-relevant biomarkers for information discovery and predictive analytics. One of the most prominent AI medical domains is segmentation algorithms. Segmentation algorithms allow the easy isolation of regions of interest (ROI) from medical images for further evaluation. However, despite its growing success, there are, naturally, some challenges. Most of these challenges are the availability of high quality and large quantities of data sufficient in training a segmentation model. Poor quality or scarcely available data could lead to data imbalances, in which classes of information from the data may not be evenly distributed.

In addition to the lack of data availability, annotations and ground truth labels required for training DL models are challenging to obtain and involve tedious and time-consuming evaluation by a clinical expert. Because of this, clinicians often rush through their annotations, often providing engineers with labels that are not true to the boundaries of the original ROI, resulting a model that may not always be discerning enough for true clinical implementation.

One potential pathway to overcoming challenging datasets for segmentation include the use of loss functions to better improve DL parameter estimation. There are already several loss functions readily available, including the binary cross entropy (BCE), weighted BCE, Focal loss, and Tversky loss, to name a few. However, the selection of the most appropriate loss function remains a challenge. Some of these loss functions are designed to account for imbalances by including penalty terms which could be modified to suit differing circumstances. However, this requires some manual work on the end-user's part. Furthermore, these loss functions tend to mimic the annotation format in which the DL was fed. For example, if polygon-shaped annotations are fed in, then polygon-shaped annotations will be fed out.

In this project, students are required to build upon previous works developed by the supervisors and continue the development of a statistically driven adaptable loss function for the purpose of accurate segmentation in DL models.

Expected Skillset:

This project will require students with a combinatorial skillset, with aptitude and interest in mathematics, statistics, and computer science required for successful completion.

Expected Outcome:
The following steps are expected to be completed as part of the project:

1. Background review[1]
    - Create a dataset that includes a comprehensive list of loss functions available and their purpose
    - Understand the fundamental role of loss function in the AI training process
2. Data collection:
    - The student will collect four open-source datasets from the Cancer Imaging Archive (TCIA). The chosen datasets must be suitable for training AI segmentation models.
3. Create a new loss function
    - Students will receive preliminary code developed by the supervisors to test and then modify as required
4. Train DL models with new and existing loss functions for comparison
    - Students will develop and train DL model with the new loss function across the various datasets collected and compare the results against DL models trained with the existing loss function (i.e., validate the new loss function's performance)
5. GitHub Release:
    - The final work will be shared on GitHub - https://github.com/xrai-lib/. Students will be listed as contributors to the repository.
6. Publication:
    - Results from this project are expected to be published in at least one journal or conference paper.

Learning Outcomes:
The students will gain experience in the following areas:
- You will develop critical thinking skills, particularly in the evaluation of the literature, problem-solving in a research setting, and how to present findings to a wide audience.
- You will learn how to communicate research findings clearly and effectively through written reports, presentations, and potential publications.
- You will improve your collaborative skills through continued discussion with mentors, peers, and experts in the field.
- You will have a deeper understanding of how mathematics, statistics, and AI models overlap, and how this knowledge can be used to develop more transparent models in the future.
- You will contribute to the development of new and novel XAI methods, thus enhancing the breadth of the field.