Diagnosis & prognosis of cardiac diseases by robust-feature selection from the complex latent space of DL-based segmentation networks.

Significance: Researchers have shown significant correlations among segmented objects or layers in medical image modalities and pathologies. Several studies shown that using hand crafted feature for disease prediction neglects the immense possibility to use deep learned features from segmentation models which may hamper the overall classification accuracy. However, directly using classification networks on medical images itself or segmented images opt out robust feature selection and may lead to overfitting and hence reduced test accuracy. To fill that gap, we want to explore different data mining techniques for feature selection to exclude redundant features from latent space of deep learned models for faster and improved disease classification and prognosis prediction.

Problem formulation: Quick diagnosis and accurate treatment by giving proper medication to patients is necessary for life threatening diseases such as acute myocardial infarction (AMI). But the Takotsubo syndrome (TTS) can mimic clinical and electrocardiographic (ECG) features of AMI and hard to distinguish between them using just echocardiogram videos (echo). Use of angiogram is the conventional way of distinguishing between these two diseases which is not only invasive, but also slow in process that may endanger the patient. In our earlier study, we demonstrated that using deep learning models as binary classifier between the two diseases can significantly improve the detection accuracy compared to the physicians and help them make the judgement calls in difficult cases [1]. Looking at the feature maps of the trained classifier, we identified that the basal septal, antero-lateral walls and the apex of the heart are extremely important in decision making of the deep learning models. We further investigated and found out that there are significant motion differences in the activated regions of the classifier feature maps. But it is impossible to distinguish the spatial and temporal features of the classifier due to the black box nature of the model. Moreover, artifacts and speckle noise in the echos can generate irrelevant and wrong features that may hamper the overall accuracy.

<u>Main challenges</u>: The main challenges of using echocardiogram video datasets are that it is extremely noisy. Moreover, the field of view and the video quality may differ for different patients due to video acquisition by different technicians and scanners. We developed a region of interest selection technique and used data augmentation to address this issue [1]. The other big challenge is to produce the manual contours to use as ground truths to train the segmentation model. We have developed a segmentation tool using the optical flow algorithm that can assist the human experts to quickly produce manual contours of the required regions. Finally, robust feature selection from the segmentation models' latent space is extremely challenging and an on-going area of research that we want to address.

<u>Existing solutions</u>: Baek et al., showed that CNNs trained to perform tumor segmentation task, with no other information than the physician contours, identify a rich set of survival-related image features with remarkable prognostication in a retrospective setting [2]. They were able to identify strong correlation between segmentation algorithm features and the disease outcomes but no dependency with any other clinical information. Same trend has also been observed from the validation over an external dataset.
Their survival prediction framework composed of two major unit (a) the U-Net segmentation network and (b) the survival prediction model. The U-Net is trained with the dataset and physician contours and features are exported from the encoder end. Next, features are clustered in an unsupervised manner. Finally, a logistic regression model is trained for survival prediction.

<u>Proposed approach</u>: Motivated by the work of Baek et al. we want to segment the significant regions of the heart such as left ventricle and use the segmentation features for classification, instead of using the echos directly to train a binary classifier. Intuitively, the segmentation features are more robust than the features of a general classifier. But due to the extreme similar characteristics, a lot of segmentation features can be highly correlated with both the diseases and make the decision making difficult.
As a starting point, we want to use both classical and advanced feature engineering techniques to identify and select the robust features from the latent space of the segmentation network and then use a well-suited machine-learning models (e.g., SVM, ensemble SVM) to classify these two diseases with improved accuracy.

<u>Evaluation plan</u>: Our echocardiogram dataset consists of 140 TTS and 160 STEMI cases. We plan to do 4-fold cross validation to validate our models.

Timeline: We plan to start with disease diagnosis. If we can collect necessary clinical data of the patients for disease prognostic predictions, we plan to publish our works in a suitable conference/journal paper this year (if possible).

Division of labor: One of the key challenges is to produce and validate enough manual contours to train the segmentation model. Both of us will work equally to generate and validate the dataset. As for developing feature selection and machine learning techniques, we plan to separately do literature search as well as implement different techniques that can produce better results by sharing ideas and findings on each of our approaches. Finally, we will select the optimal approach that produces the best result for disease diagnosis and prognosis.

References:

1. Zaman, Fahim, et al. "Spatio-temporal hybrid neural networks reduce erroneous human “judgement calls” in the diagnosis of Takotsubo syndrome." *EClinicalMedicine* 40 (2021): 101115.

2. Baek, Stephen, et al. "Deep segmentation networks predict survival of non-small cell lung cancer." *Scientific reports* 9.1 (2019): 1-10.

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