IRP Classification and Probe Positioning Failure Detection in High-Resolution Esophageal Manometry using Machine Learning

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Abstract

High-Resolution Esophageal Manometry (HRM) is the most used technique for the study of Esophageal Motility Disorders (EMD) like Achalasia type I, type II, type III [1], Jackhammer Esophagus [2], etc. The HRM catheter is inserted transnasally and positioned to cover the full length of the esophagus during the procedure. It uses as many as 36 circumferential sensors and generates heat-map-like images, representing the muscle movement in the esophagus during a swallow. These sensors transmits intraluminal pressure data through a high-resolution catheter, which is then translated into dynamic esophageal pressure topography maps.

Based on these heat-map-like images the Chicago Classification (version 3.0) [3] is applied, which is a formal analytic framework for esophageal motility disorders used to make an esophageal motility diagnosis. The diagnosis of the EDM is a time consuming manual process, doctors needs to make different measurements, like measuring the Integrated Relaxation Pressure (IRP) [5], the Distal Contractile Integral (DCI) [4], etc. on the raw HRM images and then manually apply the Chicago Classification algorithm in order to determine the exact class or type of disorder. Furthermore the esophageal motility diagnosis can be highly affected by the positioning of the catheter, which is the reason why it is critical to make sure that the positioning of the catheter is precise and there is no place for misinterpretation in the generated esophageal pressure topography maps.

In this paper we present a Machine Learning based solution for detecting probe positioning failures in HRM images, which can be used before applying the Chicago Classification algorithm, this way maximizing the precision of the esophageal motility diagnosis. Furthermore, we created a classifier to automatically determine whether the Integrated Relaxation Pressure is in the normal range or it is higher than the cut-off, based solely on the raw pressure topography images. Determining the IRP type is one of the most important step in the Chicago Classification algorithm, so this work is the first step towards automating the Chicago Classification algorithm using Machine Learning techniques. Automating this algorithm will highly reduce the costs for the hospitals, because the esophageal motility diagnosis will be automatically done, requiring only a nurse to position the catheter, so no specialist will be needed anymore.

In order to detect probe positioning failures and to classify the IRP, firstly we preprocessed the raw HRM images. The first step in preprocessing of the images was to find the region of interest, by finding the part of the image which represents the exact moment of swallowing. After this step we resized the images and we rescaled the pixel values so they can be used as input for Deep Learning models. After preprocessing the images we tried multiple Deep Learning models to classify the images as normal or abnormal images (abnormal means wrong catheter position) and to determine the exact class of the IRP. The result of the trained Neural Networks (NN) were very promising, with an accuracy and f1-score over 95% for most of the NN models that we tried. The results of these experiments are presented at the end of our article.

References

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