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Anomaly detection for the quality control of silicon sensor wafers for the CMS HGCAL upgrade

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With the approaching HL-LHC upgrade, the current endcap calorimeters of the CMS are to be replaced with the High Granularity Calorimeter (HGCAL). Most of the sensitive part of HGCAL will consist of approximately 25,000 silicon pad sensor wafers, each approximately 20 cm in diameter, covering a total area of more than 600 m^2 of silicon sensors. Electrical breakdowns have been observed during prototype testing. Those could often be attributed to the presence of various anomalies on the sensor surface, such as scratches and dust.

Therefore, visual inspection of the sensor surface might become an imperative step in the quality control program of the HGCAL sensors. A visual inspection system that is in use for this purpose consists of a programmable xy-table, microscope and a camera, which takes approximately 500 images per sensor. While the photo taking is automatised in this way, a human still has to inspect the images and look for anomalies, which is a subjective and laborious process. We are considering the application of deep learning-based tools, specifically convolutional neural networks, for the task of image classification and anomaly detection. Our goal is to use them to develop a trigger-like model that preselects images containing potential anomalies for a human to subsequently validate.

Our strategy is the implementation of an anomaly detector as an ensemble of two independent neural networks [1]. First, an autoencoder is trained to encode and decode normal images so that the reconstruction error is minimized. Thus, the error will increase in the event of anomalous input. Second, the pixel-wise reconstruction error will be given as input to a convolutional neural network for classification. In this talk, we present the task of anomaly detection in the context of HGCAL silicon sensor qualification, we present the proof-of-concept of our approach and complement this with preliminary results.

[1] N. Akchurin et al., "Deep learning applications for quality control in particle detector construction", arXiv:2203.08969 [hep-ex], 2022.

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