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An explainable-by-design end-to-end AI framework based on prototypical part learning for mass detection and classification in DBT images

In the context of the INFN next_AIM experiment, we developed an explainable-by-design framework for mass detection and classification in Digital Breast Tomosynthesis (DBT) images. DBT, an advanced X-ray imaging technique, captures multiple projections of the breast over an arc, reconstructing them into a detailed stack of slices, each with less radiation than traditional mammography. This method enhances the visualization of breast tissue, aiding in cancer detection and assessment of dense breast tissue. However, the voluminous data from DBT exams pose a challenge to radiologists' evaluation due to the time-intensive nature of the task.

To address this, we propose a dual-step framework employing deep learning (DL) to expedite the reading process while ensuring transparency in decision-making. The first step utilizes state-of-the-art neural networks, YOLO v5 and YOLO v8, to detect breast masses within DBT images. An ensemble approach is also explored for comparison. The detected masses are then classified by ProtoPNet, an explainable-by-design deep neural network that leverages prototypical part learning. This network compares image patches with learned prototypical parts, classifying the image based on these similarities, thus providing an explainable rationale alongside its predictions.

Our approach contrasts with traditional black-box models, which, despite their performance being usually higher than shallow approaches, raise concerns due to their opaque nature, and, therefore, it falls into the field of eXplainable Artificial Intelligence (XAI). Our results indicate that ProtoPNet's performance aligns with conventional ResNet-based methods, with the added advantage of interpretability.

Given the computationally intensive nature of the task, we have utilized high-performance computing facilities, including the computing center of the INFN Pisa Division, the AI@edge cluster of the Institute of Information Science and Technologies (ISTI) of the CNR, and the LEONARDO cluster of CINECA. These resources have been instrumental in managing the extensive data processing required.

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