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Modeling and analysis of prostate cancer structures alongside an incremental and supervised learning algorithm

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Advanced imaging techniques have been developed and investigated in the last years to assist radiologists in the recognition of prostate cancer. These new techniques imply, for the radiologists, a continuous and increasing amount of data to interpret and to analyze in limited periods of time. Therefore, an automated recognition system that analyzes a high number of nonlinear variables to characterize cancer and benign structures, supporting the medical diagnosis process, is desirable.

The characteristics of prostate cancer increase the risk of inaccurate reports and inter-observer variability. Hence, some computer-aided detection systems have been investigated to study the properties of prostate structures. However, a scalable and robust method applicable in real clinical conditions needs to be developed. The collection of representative data is difficult, and reference data often become available only in small and separate batches. Moreover, the current algorithms suffer from unlearning when new data is available. In this thesis, an incremental learning ensemble algorithm is presented to overcome the limitations in clinical environments, which classify cancer structures improving the accuracy and the efficiency of the recognition. The results demonstrated the superior performance of the framework in comparison to other studies, which includes correction of MRI artifacts, extraction of texture discriminants and an ensemble classifier with a dynamic learning methodology.

The proposed framework addresses several steps to achieve a suitable recognition. At first, a methodology to extract reference data is followed, including the local spread of the probability distribution of intensity values, which helps to minimize the variability and mislabeled data. A well-known drawback in magnetic resonance images is the presence of intensity artifacts that affect not only the visual inspection, but also can influence the performance of mathematical models. The correction of these artifacts involves the use of methods that do not need restrictive model assumptions and give similar intensity values to similar tissue structures.

Another important step is the examination of new discriminant features, in which associations in a multi-dimensional space contribute to discern prostate texture properties, such as contrast, regularity, smoothness or coarseness. First and second order angular independent statistical approaches and rotation invariant local phase quantization (RI-LPQ) are utilized to quantify texture information. The distribution of intensity values in a region and its relation regarding the relative position of pixels to each other is used to find new relationships to discriminate cancer.

The main step in the proposed framework is the implementation of a learning algorithm that does not forget previous or underrepresented patterns when new data becomes available. The incremental learning algorithm gives more weight to data that is difficult to classify. Moreover, the ensemble classifiers, one ensemble for each data set, combine the predictions based on a weighted majority voting algorithm focusing the estimation on the classifiers that minimize the empirical error.

The framework demonstrates the feasibility of an incremental learning algorithm being able to learn additional information from new data while preserving previously acquired knowledge and preventing unlearning. The use of texture descriptors provides more salient discriminative patterns than functional information. Furthermore, the system improves selection of information, accuracy, efficiency, scalability and robustness of the classification. The proposed computer aided tool enables radiologists to have a lower variability in diagnosis, decrease false negative rates and reduce the time to recognize and delineate structures in the prostate.