Combined unsupervised-supervised classification of multiparametric PET/MRI imaging data of the prostate

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Introduction:

Multiparametric imaging using combined modalities is increasingly used for diagnostic as well as research-driven purposes. Data thus acquired, however, are large and complex making analysis a difficult, time-consuming task. Classification algorithms are a possible solution allowing for objective and reproducible analysis of multidimensional data. Especially supervised classification algorithms were shown to yield good results e.g. in tumor detection on medical imaging data. However, a prerequisite for the application of supervised methods is the existence of a labeled training data set with known ground truth. In medical imaging, ground truth is most often defined by a spatially resolved histopathological correlation. As spatially resolved histopathology is not obtainable in many cases (e.g. brain imaging), supervised methods cannot be used directly. Unsupervised classification algorithms on the other hand do not depend on known ground truth but often produce results without biological meaning.
The purpose of this study was to design and validate a method for classification of multiparametric PET/MRI imaging data that allows for robust classification in cases where knowledge about underlying ground truth is not available. To this end we used a combined unsupervised-supervised method.

Material and Methods:

14 patients with biopsy-proven prostate cancer (mean range 86, range 51-81 years) were enrolled in this study. All patients gave their informed consent. Patients underwent a $^{[11]}$C-Choline-PET/MRI examination on a combined clinical scanner (Biograph mMR, Siemens). PET data were acquired for 15 min over the pelvic region (60 min uptake, 600 MBq $^{[11]}$C-Choline). The following MR sequences were acquired: A transversal T2-weighted TSE sequence, Diffusion Weighted Imaging (DWI) (b= 50, 800s/mm², calculation of ADCs) as well as a dynamic contrast enhanced (DCE) series using a T1 weighted 3D gradient echo sequence and subsequent modeling of parameters K_{trans} and K_{ep}. The resulting 3D data sets with fivedimensional voxels (PET, T2, ADC, K_{trans}, K_{ep}) were used for further analysis.
The proposed algorithm combines the unsupervised Spatially constrained Fuzzy C-means Algorithm (sFCM) [1] with a Support Vector Machine (SVM) classifier [2]. sFCM was applied to the single data sets and the resulting classifications were used to infer labels for the training of the SVM. The rational behind this approach is the idea that although unsupervised algorithms may produce misclassification when applied to single data sets, their application to multiple data sets will lead to overall robust results that can be used for the training of an SVM.
We chose the following parameters for the sFCM: number of classes, 2; fuzziness parameter, 1.5; parameters p,q = 1.
We chose a linear kernel for SVM training and performed 10-fold crossvalidation to avoid overfitting.
Classification results were compared to manual tumor delineation by two experienced radiologists as well as to histopathology, which was available for 3 patients after prostatectomy. Voxel-wise accuracy, false positives and false negatives were calculated. In addition, results were also evaluated qualitatively.

Results:

The proposed sFCM/SVM algorithm showed robust classification of prostate lesions with accuracy rates similar to manual tumor delineation when compared to histology (88% vs. 85%). sFCM consistently performed better than sFCM alone. Classification accuracy increased with increasing number of parameters used for classification. The addition of PET as a single parameter led to an improvement in accuracy by up to 9%. Qualitative analysis showed that all high grade prostate lesions were detected by the proposed algorithm. False positive results were seen in regions of inflammatory changes within the prostate.

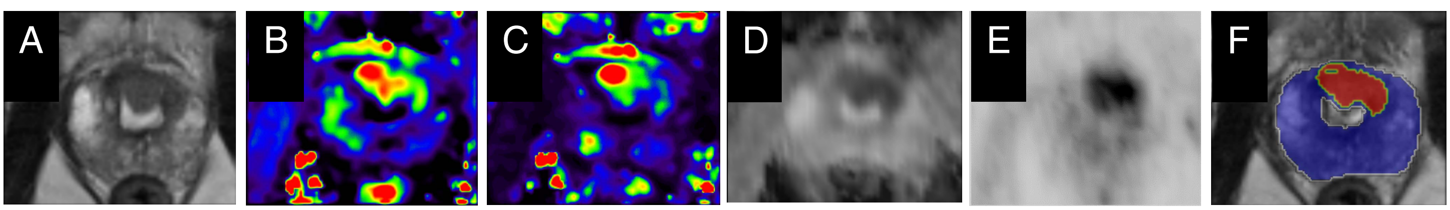

Figure: Results of the proposed sFCM/SVM algorithm: A) T2 TSE; B) Kep; C) Ktrans; D) ADC; E) PET; F) Classification results (red = tumor)

Discussion:

In this study we implemented a classification algorithm that yields robust results when applied to multiparametric imaging data without or with very limited prior information about the data. We observed accuracy of classification similar to manual tumor delineation and consistent with histopathological results. Many further applications for this approach are conceivable especially in organs without easily available spatially resolved histology (brain, lungs, liver etc.). However, we saw false positive classification in regions of inflammation. The choice of more than two clusters and further parameter optimization using more data sets may improve specificity.

Conclusion:

The presented sFCM/SVM algorithm is a promising approach for the analysis of multiparametric imaging data when knowledge about ground truth is limited. Further applications (e.g. in brain imaging) are possible.

1. Chuang, K.S., et al., *Fuzzy c-means clustering with spatial information for image segmentation.* Comput Med Imaging Graph, 2006. **30**(1): p. 9-15.
2. Li, M., Y. Cheng, and H. Zhao, *Unlabeled data classification via support vector machines and k-means clustering.* Computer Graphics, Imaging and Visualization, 2004. CGIV 2004. Proceedings. International Conference on, 2004: p. 4.