EMPrAvISE: A Computerized Decision Support System for Automated Prostate Cancer Detection from Multi-Protocol MRI

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Background: We present a novel technique, Enhanced Multi-Protocol Analysis via Intelligent Supervised Embedding (EMPrAvISE), for building a computerized meta-classifier to predict the spatial extent of prostate cancer (CaP) *in vivo* via multi-protocol (T2-weighted, Dynamic Contrast Enhanced, Diffusion-weighted) MRI data. In order to construct such a quantitative classifier, we will have to account for differences in scale, alignment, and information associated with these protocols. Previous attempts at building computerized CaP classifiers [1,2]: (1) do not use rigorous automated registration techniques to map spatial extents of CaP onto multi-protocol *in vivo* MRI (to train the classifier), (2) do not rigorously align the multiple MRI protocols to correct for acquisition differences (in order to best combine the multi-protocol MRI information), and (3) do not truly exploit the all class discriminatory information captured by multiple MRI protocols.

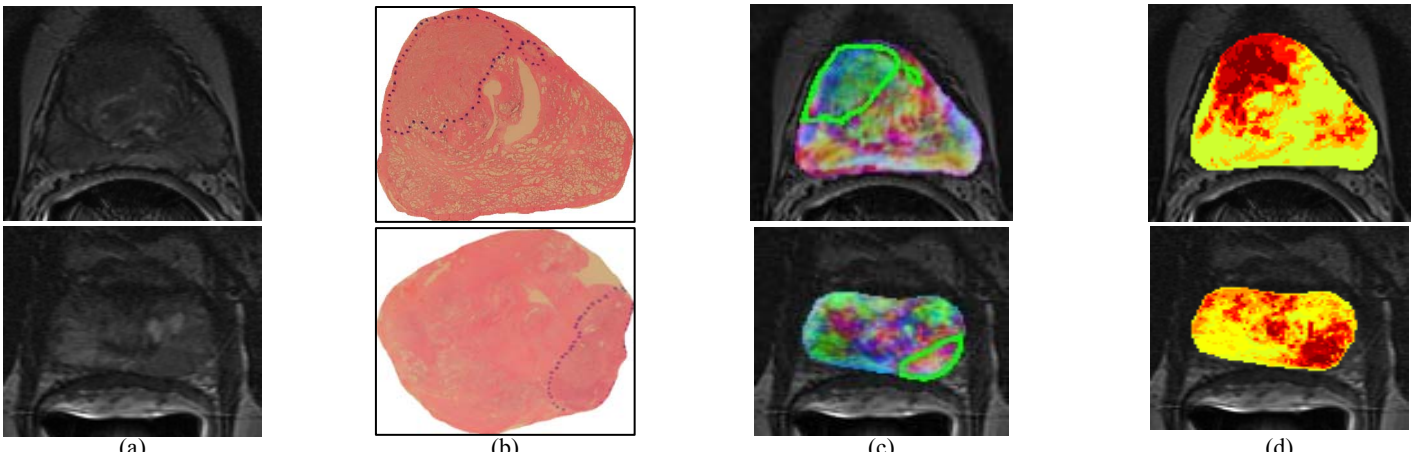
Methods: 12 *in vivo* patient studies comprising 3 Tesla T2w, DCE, and DWI MRI (Genesis Signa LX Excite, GE) were obtained. Acquisition was done using a combined torso phased array and endorectal coil with imaging parameters as summarized alongside. DCE images were obtained after mechanical bolus injection (Spectris®, MEDRAD) of gadopentetate dimeglumine (Magnevist®; Berlex Laboratories) at a dose of 0.1 mmol/kg of body weight. Two pre-contrast and five post-contrast sequential acquisitions are obtained. DWI imaging had a B-value= 0, 1000; number of directions = 25. Corresponding H&E stained whole-mount histological sections (WMHS) with pathologist-delineated regions of CaP extent were also acquired (via radical prostatectomy specimens). 39 corresponding slices were selected based on visual landmarks that could be identified on T2w MRI and WMHS. EMPrAvISE comprises the following steps: (i) T2w MRI and ADC maps (from DWI MRI) are brought into alignment with DCE MRI via volumetric affine registration, to correct for scale and acquisition differences. (ii) The WMHS is non-linearly registered to the T2w MRI using the technique proposed in [3] to correct for non-linear deformations between T2w and WMHS. (iii) CaP extents from WMHS are thus mapped onto all 3 aligned MRI protocols. (iv) Texture features, based on responses to various filter and gray level co-occurrence operators [4], are calculated from T2w and ADC, respectively. Time-point information is used to characterize DCE MRI. (v) An ensemble of representations (obtained via dimensionality reduction, DR) is constructed based on all the multi-protocol feature descriptors [4]. (vi) These representations are then combined such that class discrimination between CaP and non-CaP regions is best optimized. (vii) The final combined DR representation from step (vi) is automatically classified at a per-pixel level via a probabilistic boosting tree classifier (PBT) [5] using CaP labels obtained via step (iii).

Parameters	T2w	DCE (T1w)	DWI
FOV (cm)	12	28-22	24
Matrix size	320 × 224–192	256 ×224	256 ×192
Slice thickness (mm)	1.5-2	2-3	3
TR (msec)	6375	7.1	6500
TE (msec)	165	2.1	80.6
Acquisition time (min)	5-7	92sec × 7 = 10min 44s	7
	FSE	FSE	EPI

Results: A leave-one-out cross validation strategy over the 39 slices (selected from 12 studies) was used to evaluate performance of a PBT based on (1) T2w texture features, (2) ADC map texture features, (3) DCE time point information, (4) a feature set comprising all of (1)-(3), (5) an EMPrAvISE representation. Corresponding accuracy values for predicting spatial extent of CaP at a pixel level, with per-pixel evaluation against CaP regions mapped onto MRI as a gold standard: (1) T2w: 0.62±0.22, (2) ADC: 0.65±0.21, (3) DCE: 0.62±0.14, (4) T2w+ADC+DCE: 0.67±0.21, (5) EMPrAvISE: 0.73±0.13.

Concluding Remarks: Quantitative classification based on multi-protocol MRI integration, corresponding to feature sets (4) and (5) above, outperforms classification based on the individual protocols, feature sets (1)-(3) above, which corroborates with current clinical experience [1,2]. The highest accuracy for predicting spatial extent of CaP at a pixel level corresponds to using EMPrAvISE, with a similar performance shown via ROC analysis as well. All improvements demonstrated by EMPrAvISE were noted to be statistically significant. We have thus successfully demonstrated the utility of a novel computerized decision support system applied to multi-protocol (T2w, DCE, DWI) MRI for prostate cancer detection.

References: [1] Chan, I. et al, *Medical Physics*, 2003, v30(9): p. 2390-2398, [2] Liu, X. et al, *IEEE Trans Med Imag*, 2009, v28(6): p. 906-915, [3] Chappelow, J. et al, in *Proc ISBI*, 2010, p. 376-379, [4] Anon, [5] Tu, Z., in *Proc. IEEE ICCV*, 2005, p. 1589–1596.



(a) (b) (c) (d)

(a) Sample T2w MRI slice, (b) corresponding WMHS for this slice, with CaP extent outlined in blue, (c) RGB colormap of EMPrAvISE representation, overlaid on (a), with registered CaP extents from (b) outlined in green. Note that regions in (c) are colored based on similarities captured by the EMPrAvISE technique. (d) Final EMPrAvISE-based pixel-level CaP heatmap, where red corresponds to a higher probability of CaP presence, obtained via PBT classification of (c). Note significant correspondence between green outlines in (c) and red regions in (d).