

Computer-Aided Diagnosis for Prostate Cancer using mp-MRI

PhD Defence
28th November 2016

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- ① Introduction
- ② CAD and mp-MRI
- ③ I2CVB

① Introduction

Motivations

The prostate organ

Prostate carcinoma

Screening

CAD and mp-MRI

Research objectives

② CAD and mp-MRI

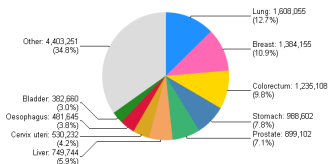
③ I2CVB



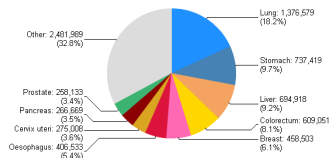
Motivations



Statistics



(a) # of cancer cases



(b) # of cancer deaths

Implications, image source¹

- ▶ 2nd most frequently diagnosed men cancer
- ▶ Accounting for 7.1% of overall cancers diagnosed
- ▶ Accounting for 3.4% of overall cancers death

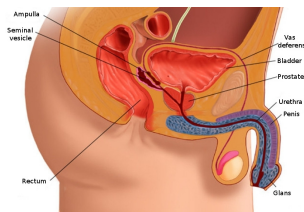
¹J. Ferlay et al. "Estimates of worldwide burden of cancer in 2008: GLOBOCAN 2008". In: *Int. J. Cancer* 127.12 (Dec. 2010), pp. 2893–2917.



The prostate organ



Anatomy



Localization of the prostate organ, image source²

Characteristics

- ▶ Height: 3 cm
- ▶ Depth: 2.5 cm
- ▶ Weight: 7 g to 16 g

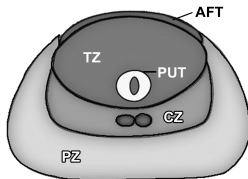
²Geckmedia. *Natom Anatomy*. French. June 2011. url: <http://www.natomshop.com/>.



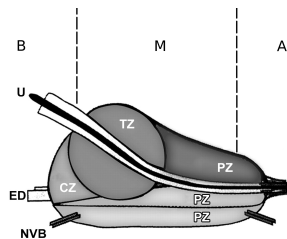
The prostate organ



Anatomy



(a) Transverse plane



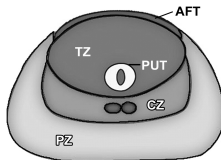
(b) Sagittal plane

Prostate zones - AFT: anterior fibromuscular tissue, CZ: central zone, ED: ejaculatory duct, NVB: neurovascular bundle, PUT: periurethral tissue, PZ: peripheral zone, U: urethra, TZ: transitional zone, B: base, M: median, A: apex; image source³

³Y. J. Choi et al. "Functional MR imaging of prostate cancer". In: *Radiographics* 27 (2007), pp. 63–75.



Prostate carcinoma (CaP)



CaP development

- ▶ Slow-growing → 85 %
- ▶ Fast-growing → 15 %
- ▶ CaPs in CG are more aggressive

Zonal predisposition

- ▶ PZ → 70 % to 80 %
- ▶ TZ → 10 % to 20 %
- ▶ CG → 5 %

Goals

- ▶ Detect CaP
- ▶ Distinguish slow- from fast-growing CaP
- ▶ Active surveillance vs. prostatectomy/other treatments



Screening

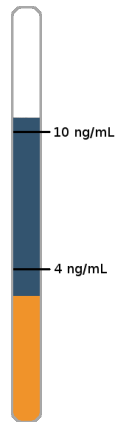


Prostate-specific antigen

- ▶ $> 10 \text{ ng mL}^{-1} \rightarrow \text{biopsy}$
- ▶ From 4 ng mL^{-1} to 10 ng mL^{-1}
 $\rightarrow \frac{\text{orange}}{\text{orange} + \text{blue}} > 15\% \rightarrow \text{biopsy}$
- ✗ Not reliable

"Blind" transrectal ultrasound biopsy

- ▶ Take samples from different locations
- ▶ Grade using Gleason score
- ✗ Invasive procedure
- ✗ Lead to false positives & negatives



● free PSA
● protein-linked PSA



Screening



Prostate-specific antigen

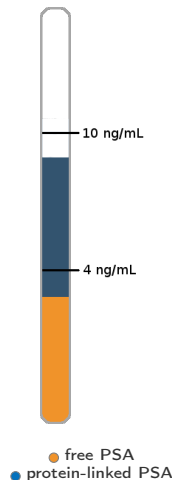
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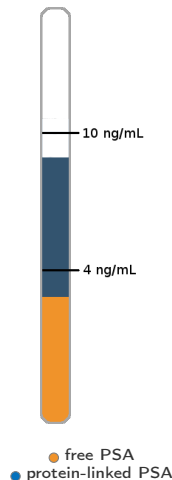


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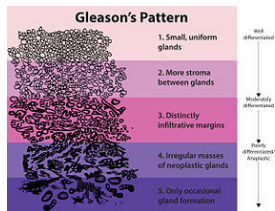


Image source: <https://goo.gl/fEVQXQ>



Screening



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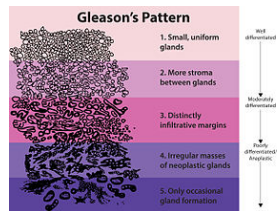


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Pros

- ✓ Reduce CaP-related mortality from 21 % to 44 %⁴

“Blind” transrectal ultrasound biopsy

- ▶ Take samples from different locations
- ▶ Grade using Gleason score
- ✗ Invasive procedure
- ✗ Lead to false positives & negatives

Cons

- ✗ Up to 30 % of over-diagnosis⁵
- ✗ Up to 35 % of undiagnosed CaP⁶
- ✗ Biopsies are invasive

⁴Fritz H. Schröder et al. “Prostate-cancer mortality at 11 years of follow-up”. In: *New England Journal of Medicine* 366.11 (2012), pp. 981–990.

⁵G. P. Haas et al. “Needle biopsies on autopsy prostates: sensitivity of cancer detection based on true prevalence”. In: *J. Natl. Cancer Inst.* 99.19 (Oct. 2007), pp. 1484–1489.

⁶A. V. Taira et al. “Performance of transperineal template-guided mapping biopsy in detecting prostate cancer in the initial and repeat biopsy setting”. In: *Prostate Cancer Prostatic Dis.* 13.1 (Mar. 2010), pp. 71–77.



CAD and mp-MRI



Current trendy techniques: mp-MRI

- ✓ Less invasive technique

Human diagnosis using mp-MRI

- ✗ Need further investigation of the mp-MRI modalities
- ✗ Low repeatability
 - ▶ Observer limitations
 - ▶ Complexity of clinical cases

Emergence of CAD

- ▶ CADe → detection of potential lesions
- ▶ CADx → diagnosis regarding those lesions



Research objectives



Propose a mp-MRI CAD for CaP

- ▶ Study and investigate the state-of-the-art on MRI CAD for CaP
- ▶ Identify the scientific barriers
- ▶ Design a mp-MRI CAD addressing these issues
- ▶ Investigate and analyze the proposed CAD

① Introduction

② CAD and mp-MRI

- MRI modalities
- The MedIA evil

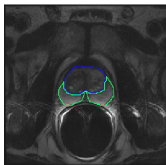
③ I2CVB



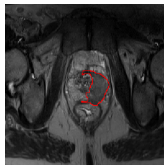
MRI modalities



T₂W-MRI



(a) Healthy



(b) CaP PZ



(c) CaP CG

Healthy

- ▶ Intermediate to high-signal intensity (SI) in PZ
- ▶ Low-SI in CG

CaP

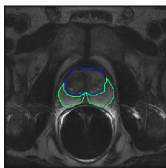
- ▶ Low-SI
- ▶ Round and ill-defined mass in PZ
- ▶ Homogeneous with ill-defined edges in CG



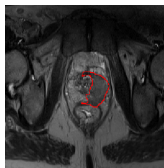
MRI modalities



T₂W-MRI



(d) Healthy



(e) CaP PZ



(f) CaP CG

Pros

- ▶ Highest spatial resolution
- ▶ Anatomy nicely depicted

Cons

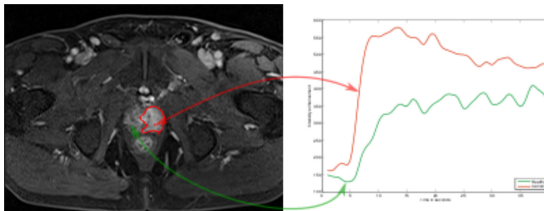
- ▶ Low sensitivity in CG
- ▶ Lower specificity due to outliers



MRI modalities



DCE-MRI



Green: healthy - Red: CaP

Healthy

- ▶ Slower wash-in, wash-out, time-to-peak enhancement
- ▶ Lower integral under the curve, max SI

CaP

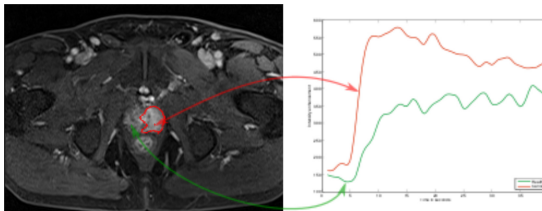
- ▶ Faster wash-in, wash-out, time-to-peak enhancement
- ▶ Higher integral under the curve, max SI



MRI modalities



DCE-MRI



Green: healthy - Red: CaP

Pros

- ▶ Information about vascularity

Cons

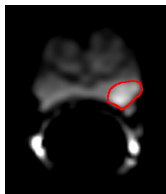
- ▶ Spatial mis-registration
- ▶ Lower spatial resolution than T_2W -MRI
- ▶ Difficult detection in CG



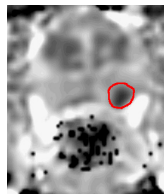
MRI modalities



DW-MRI - ADC



(a) DW MRI



(b) ADC

Healthy

- ▶ DW-MRI: lower SI
- ▶ ADC: higher-SI

CaP

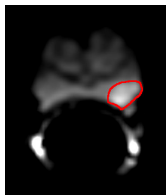
- ▶ DW-MRI: higher SI
- ▶ ADC: lower-SI



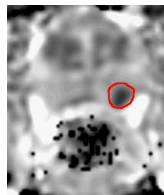
MRI modalities



DW-MRI - ADC



(c) DW MRI



(d) ADC

Pros

- ▶ Information about tissue structure
- ▶ ADC correlated with Gleason score

Cons

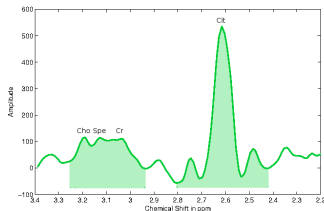
- ▶ Poor spatial resolution
- ▶ Variability of the ADC coefficient



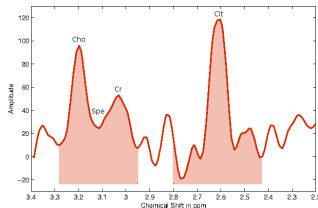
MRI modalities



MRSI



(a) Healthy



(b) CaP

Healthy

- ▶ High citrate
- ▶ Moderate choline and spermine

CaP

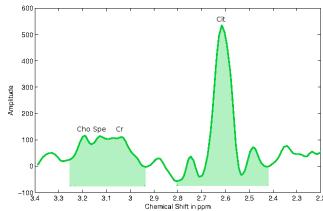
- ▶ Decrease of citrate and spermine
- ▶ Increase of choline



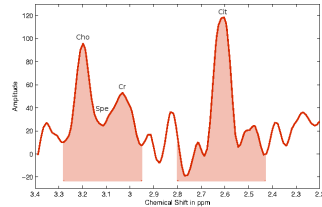
MRI modalities



MRSI



(c) Healthy



(d) CaP

Pros

- Citrate correlated with Gleason score

Cons

- Low spatial resolution
- Variation inter-patients



The Medical Imaging evil



The reasons of a nightmare

→ Multidisciplinary competences: medical doctors vs. computer scientists

Some examples

- ▶ Delay in the data acquisition
- ▶ Interest differences between the different core competences
- Lack of interest

The keystones needed

- ▶ Common datasets
- ▶ Algorithms comparisons
- ▶ Full benchmarking



The Medical Imaging evil



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The Medical Imaging evil



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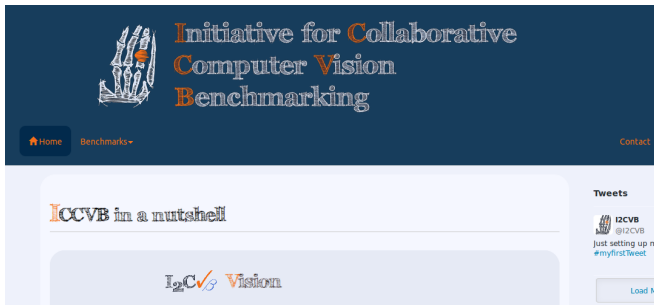
- ▶ Common datasets
- ▶ Algorithms comparisons
- ▶ Full benchmarking



Overview



I₂C_vβ Platform



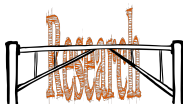
- Development of a web platform



Manifesto



I₂C_{VB} Vision



- Democratization of the ability to research

I₂C_{VB} Mission



- Open data; evaluation methods; comparison framework; reporting platform

I₂C_{VB} Protagonists



- Research groups and individuals from all walks of life to shape a transparent community

I₂C_{VB} Strategy



- Transferring successful practises from Free Software and Quality Management



Prostate dataset



Multi-parametric MRI

- ▶ Cohort of 20 patients
- ▶ T₂W MRI, DCE MRI & ADC
- ▶ 3 Tesla whole body MRI without endorectal coil

Ground-truth

- ▶ Delineations: prostate - zones - CaP
- ▶ Healthy: 2 vs. CaP: {PZ: 13, CG: 3, PZ + CG: 2 }