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Multi-Organ Segmentation using Vantage Point Forests and Binary Context Features

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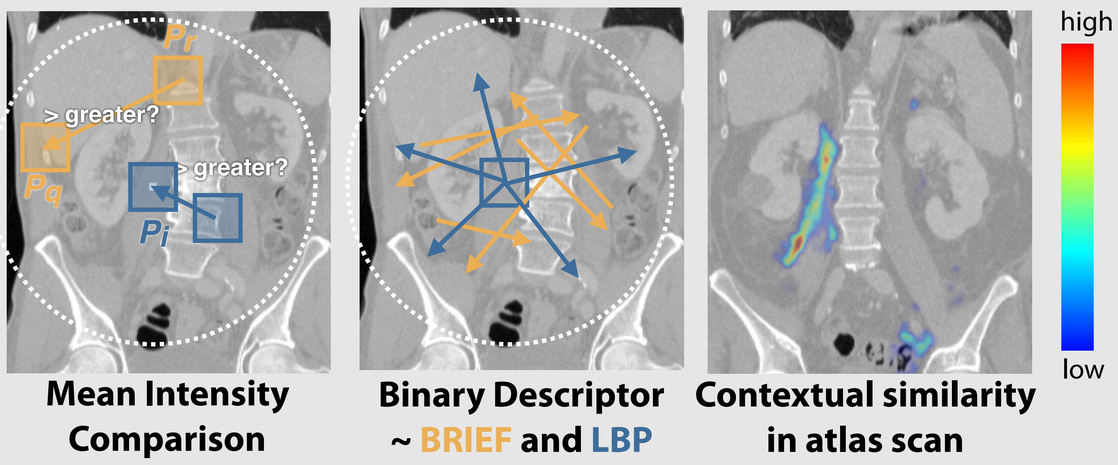
Highlights / Contributions

- **Accurate CT multi-organ segmentation**: Dice 84-88%
- Run-times of **few seconds** on single CPU
- **Overcome** limitations of **axis-parallel** splits in decision trees
- Novel highly efficient classifier: **Vantage Point Forest**
- **Source-code** available: http://mpheinrich.de/research.html#vpg

1. Binary Contextual Descriptors

- Combines several weak mean pixel intensity comparisons
- Fixed random sampling layout (640 pairs) in neighbourhood
- **Highly discriminative binary descriptor** $\mathbf{h}_i$



Mean Intensity Comparison | **Binary Descriptor ~ BRIEF and LBP** | **Contextual similarity in atlas scan**

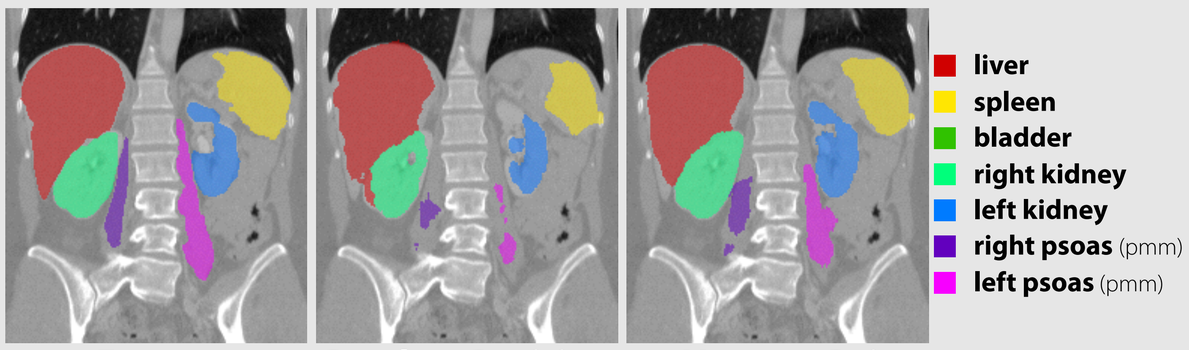
Hamming Distance between descriptors

- Counting number of dissimilar bits (`popcount`)
- **Orders of magnitudes faster** than mutual info. / SSD

4. Experiments and Results

VISCERAL Anatomy 3 Dataset[1]

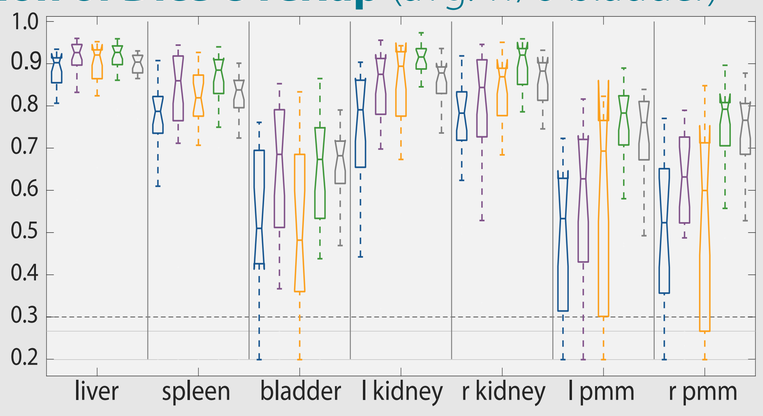
- 20+10 abdominal ceCT scans / Evaluation on 7 organs



Expert Segmentation | **Random Decision Forest** | **Vantage Point Forest**

Quantitative Evaluation of Dice Overlap (avg. w/o bladder)

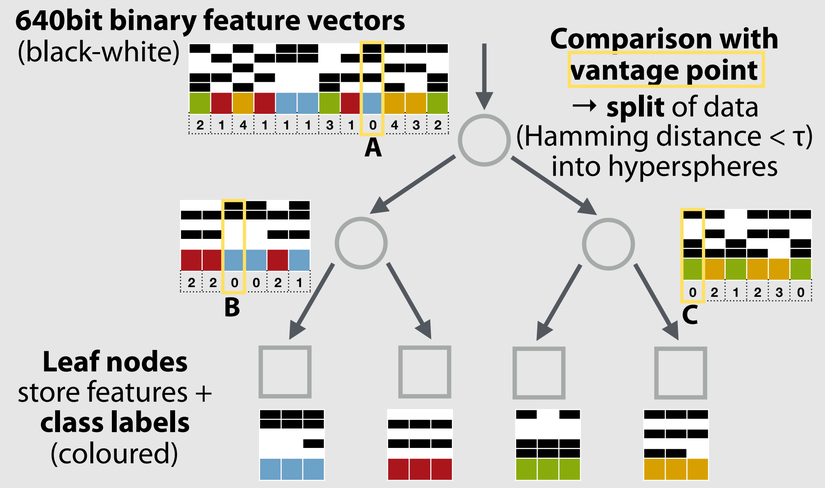
Random Forest (RDF)	
binary + regular	0.68
float + regular	0.74
Vantage Point Forest (VPF)	
binary + regular	0.74
+kNN binary + reg.	**0.84**
kNN binary w/o reg.	0.81
Keypoint Transfer	0.68



→ improved Dice by 10% against best RDF variant

2. Vantage Point Forest

- **Split function based on Hamming distance** of full-length descriptor between sample and vantage point



VP tree originally introduced for clustering of real-valued data in 1993[2]

1. randomly **pick vantage point** from all samples at current node
2. **calculate Hamming distance** of VP to all other samples
3. sort by distance and **split data into left and right child nodes**
   alternative split criteria employing class labels possible
4. **recursively repeat** 1.-3. until specified leaf size is reached

Ensemble of Vantage Point Trees

- **Improved generalisation:** randomisation at VP selection
- **Retrieve samples** from leaf nodes **of all trees** (in test):
  +**linear kNN search** for higher accuracy (cache-efficient)

→ **Higher performance** than state-of-art **approximate kNN**

→ Fast training of oblique decision trees (15 sec for forest)

3. Regularisation with Multilabel Random Walk

Upsample and refine probabilistic output (edge-preserving)

$$\sum_{\mathbf{x}} \frac{1}{2}(P(\mathbf{x})^y - P(\mathbf{x})^y_{reg})^2 + \sum_{\mathbf{x}} \frac{\lambda}{2}||\nabla P(\mathbf{x})^y_{reg}||^2$$

Fast implementation of successive-overrelaxation solver

Outlook / Future Work

- VP Regression Forest for landmark localisation[3]
- General purpose approx. kNN for retrieval / image registration
- Learning of problem specific feature selection + multiple stages

Literature

(1) Jiménez-del-Toro et al.: "Cloud–based Evaluation of Organ Segmentation and Landmark Detection Algorithms: VISCERAL Anatomy Benchmarks" IEEE Trans Medical Imaging 2016

(2) Yianilos: "Data structures and algorithms for nearest neighbor search in general metric spaces" ACM SIAM 1993

(3) Heinrich, Oktay: "Accurate Intervertebral Disc Localisation and Segmentation in MRI using Vantage Point Hough Forests and Multi-Atlas Fusion" MICCAI Computational Methods and Clinical Applications for Spine Imaging 2016

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