3D Riesz–wavelet Based Covariance Descriptors for Texture Classification of Lung Nodule Tissue in CT


SaAT6.6
August 29th, 2015
Motivation + Contribution

- **(Statistical)** feature extraction and representation
- Dictionary **modelling of lung/nodule** tissue areas
- **Classification** of lung nodule areas
  (solid / ground glass opacity -GGO / healthy)
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**Goal and application**

Supervised learning of region classes from **texture**
Robustness to size and shape **variations**
Applications: **tissue modelling**, classification, segmentation
Related work

Clinical domain

- 3D visualization and annotation software
- Manual delineation with expertise of clinicians
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Computer vision + Machine Learning domain
- 3D features: Riesz transform, 1\textsuperscript{st} and 2\textsuperscript{nd} order visual cues
- 3D descriptors: MCOV, 3D-SIFT, SHOT, THRIFT...
- Linear/non-linear (un)supervised classification methods: CNN, Kernel-SVMs, Sparse coding, Bag-of-visual features...
Intuition - features

Riesz-wavelet transform as texture features

Figure 1: Lung nodule CT slice with corresponding Riesz filter responses

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1A. Depeursinge et al., ”Lung Texture Classification Using Locally–Oriented Riesz Components”, in MICCAI 2011
Intuition - feature representation (in 3D)

3D Riesz-covariance models

Figure 2: 3D CT volume and associated Riesz-covariance descriptor
3D Riesz-Covariance descriptors

\[
\Phi(ct, v) = \{ \phi_{x,y,z}, \forall x, y, z \in v \} \quad (1)
\]

\[\phi_{x,y,z} = \left( R_{x,y,z}^{(n_1,n_2,n_3)}, \|R\|_{x,y,z, ct_{x,y,z}} \right) \quad (2)\]

\[
RieszCov(\Phi(ct, v)) = \frac{1}{N-1} \sum_{i=1}^{N} (\phi_{x,y,z} - \mu_{\phi}) (\phi_{x,y,z} - \mu_{\phi})^T \quad (3)
\]
Covariance model benefits

- Common framework for statistical data modelling.
- Features $\equiv$ samples of $n$–dim joint distributions.
- Second order moment statistics ($n \times n$ covariance matrices).
- Covariances manifold ($\text{Sym}_d^+$) $\Rightarrow$ analytical modelling Riemannian space ported machine learning techniques.
Covariance descriptors - $\text{Sym}_d^+$ Riemannian space

\[ x = \log_Y(X) = Y^{\frac{1}{2}} \log \left( Y^{-\frac{1}{2}} XY^{-\frac{1}{2}} \right) Y^{\frac{1}{2}} \] (4)

\[ \hat{x} = \text{vect}(x) = (x_{1,1}, x_{1,2}, \ldots, x_{1,d}, x_{2,2}, x_{2,3}, \ldots, x_{d,d}) \] (5)

\[ \delta(X, Y) = \sqrt{\text{Trace} \left( \log \left( X^{-\frac{1}{2}} YX^{-\frac{1}{2}} \right) \right)} \] (6)
Data gathering

Ground-truth:

- 95 patients (from Stanford Hospital and Clinics)
- Biopsy-proven early stage non-small cell lung carcinoma
- Nodule regions delineated in CTs by clinicians
- Processing with MATLAB software: isotropic voxels of 0.8 mm³
Data samples

**GGO vs. Solid lung nodule tissue components (vs. healthy lung)**

**Figure 3:** Lung nodule Riesz filter responses - GGO component

**Figure 4:** Lung nodule Riesz filter responses - solid component
Bag-of-covariances

Standard bag-of-visual features paradigm.
Sub-sampling of partial class regions for a complete dictionary modelling
Bag-of-covariances

- Dictionary $D \equiv \hat{x}^c_{v,p} = \text{vect}(\log_I (\text{RieszCov}_v^C, P))$
- Training set: modelling frequencies of words in $D$

Classification decision: $\text{class}(ct) = \arg\min_i D(h_{ct}, h_i)$
Experimental setup

Data sets:
- 35 patients for model learning, 60 for test set.
- 60 words per class (dictionary size, $3 \times 60 \times 35 = 3600$)
- 10-fold cross-validation.

Quantitative evaluation w.r.t. ground-truth:
- Avg. sensitivity (TP / TP+FN) = 82.2%
- Avg. specificity (TN / TN+FP) = 86.2%
Conclusions

- Computer vision and Machine Learning to the service of medical knowledge
- Statistical design for a robust solution
- Easily extendible framework
Future work

- More patients and bigger data collection
- Different modelling contexts for concrete problems
- Exploit the covariance-based descriptor space for different Machine Learning techniques (clustering, classification, regression...)
Thanks for your attention

Questions?

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