Natural Material Recognition with Illumination Invariant Textural Features

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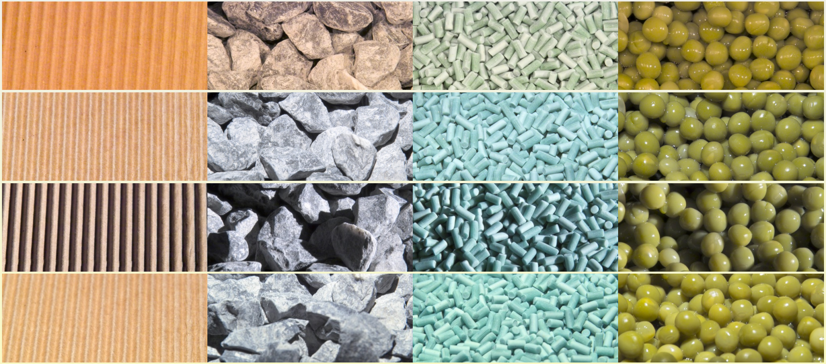
Real Scene – Illumination Dependency

Amsterdam Library of Textures (ALOT)



http://staff.science.uva.nl/~mark/ALOT/ [Burghouts and Geusebroek, 2009]

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Proposed Method Properties

Illumination variation:

- Illumination spectrum .... invariant
- Local intesity (cast shadows) ..... aprox. invariant
- Illumination direction .... robust

Unknown illumination conditions.

Single training image per material (texture).

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1. Gaussian-downsampled pyramid with K levels
2. Markovian texture representation
3. Estimate of MRF model parameters
4. **Illumination invariants are derived from the model parameters**
5. Illumination invariant feature vectors
6. Feature vectors are compared in L_1/FC norms

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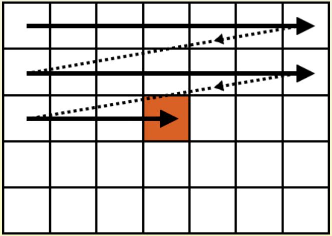
MRF-CAR Model

$$Y_r = \sum_{s \in I_r} A_s Y_{r-s} + \epsilon_r$$

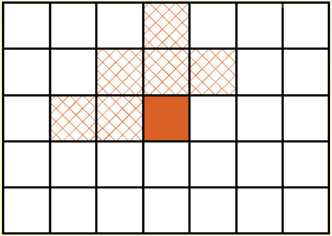
r, s	pixel multiindices, $r =$ (row, column)
Y_r	vector value (R, G, B) at texture position r
I_r	causal contextual neighbourhood with size η
A_s	**unknown parameter matrices**
ϵ_r	white noise with zero mean and unknown covariance matrix

Model Parameter Estimation

Analytical recursive Bayesian estimate for all statistics (A_s, ϵ)



movement



neighbourhood I_r

Model Parameter Estimation

$$Z_r = [Y_{r-s}^T : \forall s \in I_r]^T \quad \text{data vector}$$
$$\hat{\gamma} = [A_s : \forall s \in I_r] \quad \text{parameter matrices estimate}$$

Bayesian estimate from the process history

$Y_1 \cdots Y_{t-1}$ **,** $Z_1 \cdots Z_{t-1}$ **:**

$$\hat{\gamma}_t \approx \left(\sum_r^{t-1} Z_r Z_r^T \right)^{-1} \left(\sum_r^{t-1} Z_r Y_r^T \right) \approx \left(V_{zz,(t-1)} \right)^{-1} V_{zy,(t-1)}$$

$$V_{yy,(t-1)} \approx \sum_r^{t-1} Y_r Y_r^T \quad \text{used in noise estimation,}$$
$$\lambda_t \quad \text{used in noise estimation}$$

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$V_{yy,(t-1)} \approx \sum_r^{t-1} Y_r Y_r^T$ used in noise estimation,
λ_t used in noise estimation

Illumination Invariance

Two images Y, $\tilde{Y}$ of the same surface illuminated with different illumination spectra:

$$A_s \approx B^{-1} \tilde{A}_s \, B$$

Illumination Invariants:

1. trace: $\operatorname{tr} A_s$ $\quad s \in I_r$
2. eigenvalues: $\nu_{s,j}$ of A_s $\quad s \in I_r, \;\; j = 1, \ldots, C$

C is number of spectral planes

Illumination Invariants

3. $\beta_1 = \log\left(\frac{1}{r-t}|\lambda_r||\lambda_t|^{-1}\right)$
4. $\beta_2 = \log\left(\frac{1}{r-t}|V_{zz(r)}||V_{zz(t)}|^{-1}\right)$
5. $\beta_3 = \log\left(|V_{zz(r)}||\lambda_r|^{-\eta}\right)$
6. $\beta_4 = \operatorname{tr}\left\{V_{yy(r)}\lambda_r^{-1}\right\}$
7. utilising prediction probability $p(Y_r|Y^{(r-1)})$
8. utilising model probability $p(M|Y^{(r)})$
9. ...

Experimental Setup

Textures:

- Amsterdam Library of Textures (ALOT)
- 4 cameras, 6 illumination directions,
  1 additional illumination with different spectrum
- high resolution RGB images (min 1536×660)
- 250 materials

Experimental Setup

Tests:

1. [Burghouts and Geusebroek, 2009] without rotation, separate training and test sets (6 + 6 images), perspective projection
2. Single training image per material (14 images per material) no perspective projection

Classification:

- Nearest neighbour classification
- 10^3 random samples of training images

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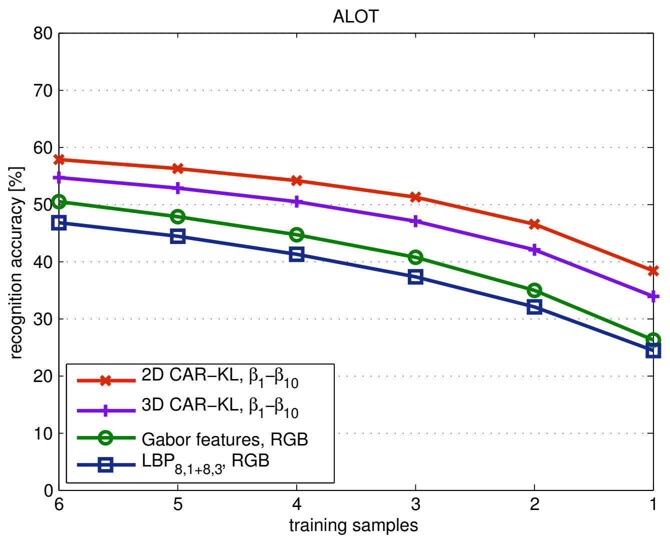
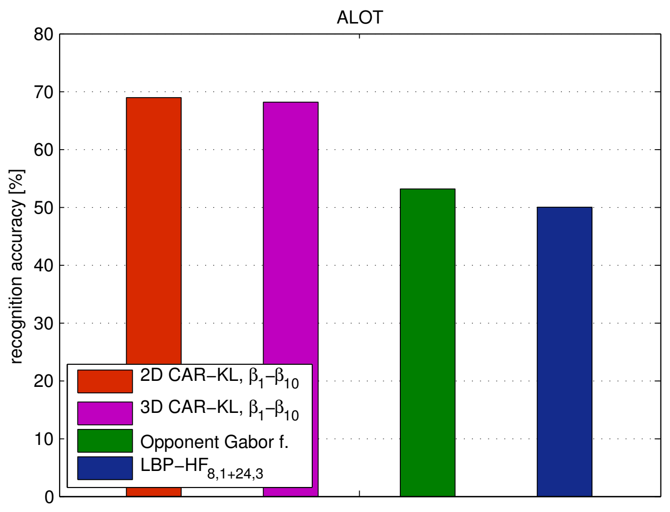
Results – [BG, 2009] Without Rotation



Results – Single Training Images



Conclusion

Summary:

- Invariant to illumination spectrum and cast shadows
- Robust to illumination direction
- Illumination knowledge not needed
- Single training image per material
  (for limited viewpoint variation)

- 9 - 16 % improvement over Gabor features, LBP

Future Plans:

- Rotation invariance
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Demonstration

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Thank you for your attention

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References

- Amsterdam Library of Textures ALOT.
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- G. J. Burghouts and J. M. Geusebroek.
  Material-specific adaptation of color invariant features.
  Pattern Recognition Letters, 30:306–313, 2009.
- P. Vacha and M. Haindl.
  Natural material recognition with illumination invariant textural features. In *Proceedings of the 20th International Conference on Pattern Recognition, ICPR 2010, Istanbul, Turkey*. IEEE, 2010. (in press).