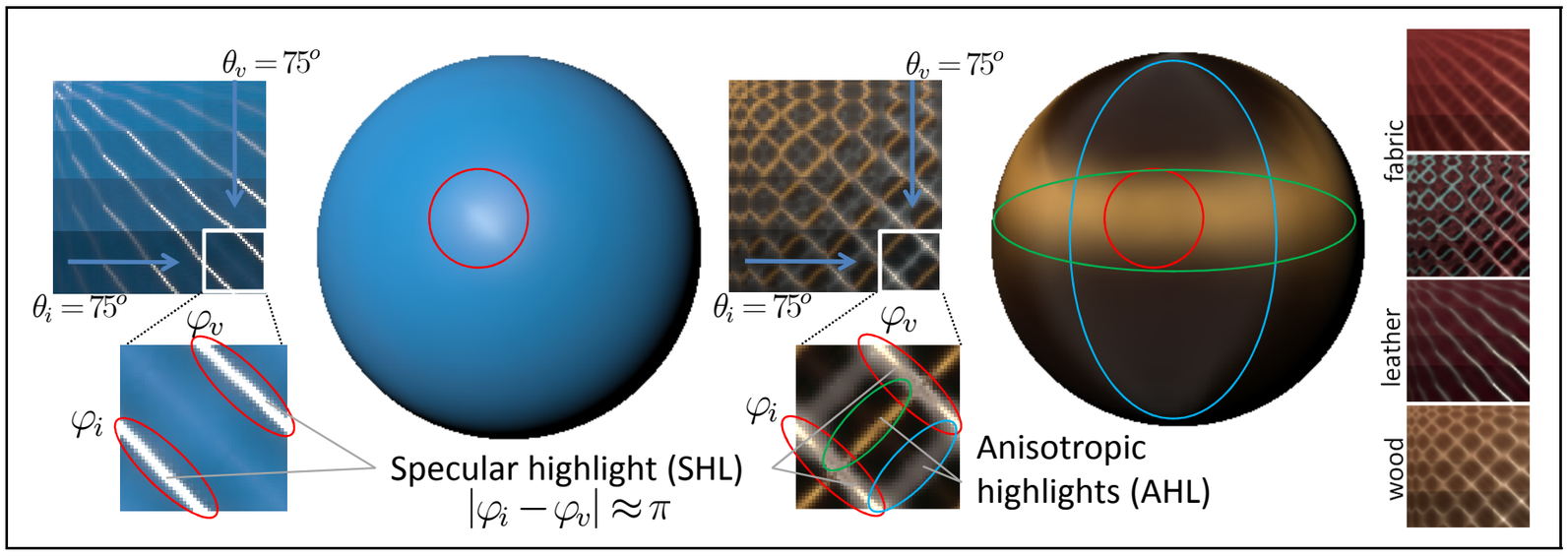
Materials Classification using Sparse Gray-Scale Bidirectional Reflectance Measurements

Jiří Filip[1] **Petr Somol**[1,2]

[1] Institute of Information Theory and Automation of the CAS, Prague [2] Faculty of Management, Prague University of Economics, Czech Republic

{filipj,somol}@utia.cas.cz

Material recognition applications use typically color texture-based features; however, the underlying measurements are in several application fields unavailable or too expensive (e.g., due to a limited resolution in remote sensing). Therefore, bidirectional reflectance measurements are used (dependent on illumination and viewing directions). But even measurement of such BRDF data is very time- and resources-demanding. We use dependency-aware feature selection method to identify very sparse set of the most discriminative bidirectional reflectance samples that can reliably distinguish between three types of materials from BRDF database – fabric, wood, and leather. We conclude that ten gray-scale samples primarily at high illumination and viewing elevations are sufficient to identify type of material with accuracy over 96%. We analyze estimated placement of the bidirectional samples for discrimination between different types of materials. The stability of such directional samples is very high as was verified by an additional leave-one-out classification experiment. We consider this work a step towards automatic method of material classification based on several reflectance measurements only.

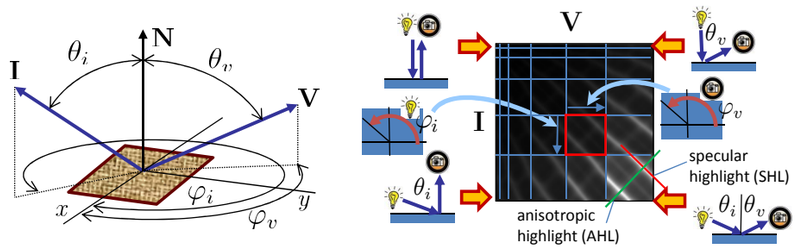


Motivation

Real-world countless varieties of materials:

- **Challenge**: automatic material classification based on sparse gray-scale directional reflectance samples
- **Approach**: important directional samples identification using feature selection
- **Applications**: remote sensing, paint, food, recycling industry

Bidirectional Reflectance – BRDF



BRDF:

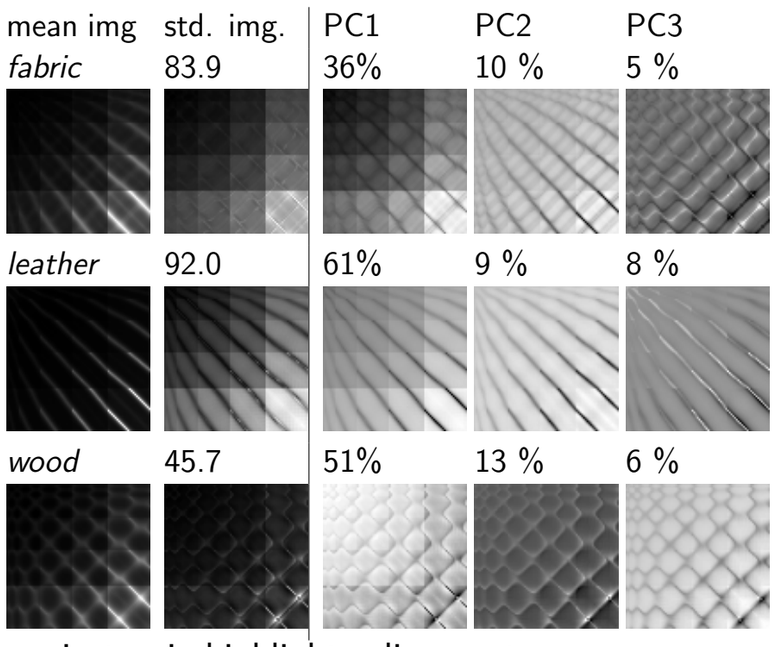
- view/illumination dependent appearance
- 4D distribution function – view/illumination reciprocity, energy conservation, non-negativity

Test BRDF Dataset

UTIA BTF database **http://btf.utia.cas.cz**

BRDFs: 3 categories: **fabric**, **leather**, **wood**
3321 directional samples, angular step in 15^o

Material Categories Analysis



- anisotropic highlights alignment necessary when comparing different BRDFs

Feature Selection

- **Problem formulation**: N-dimensional feature space $\rightarrow$ classifying objects described by means of features $f_1, f_2, \ldots f_N$ $\rightarrow$ mutually exclusive classes
- **Task**: optimal selection of subset of the most informative features

Dependency-Aware Feature Ranking:

Somol P., Grim J., Pudil P.: IEEE SMC, 2011, pp. 502-509

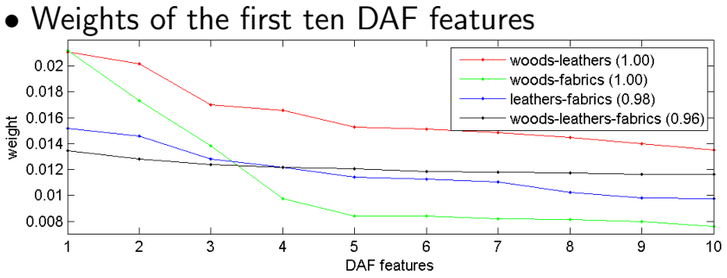
- Assume set of all features $F = \{f_1, f_2, \ldots, f_N\}$
- for each subset of features $S \subset F$ (probe) a feature selection criterion $J(\cdot)$ is evaluated to measure the quality of S

Our configuration:

- FST3 library **http://fst.utia.cas.cz/**
- 3321 features $\times$ 146/16/19 samples (2-3 classes)
- criterion function $J()$ – classification using linear SVM with one-level cross-validation
- 300 000 probes, computational time 6 hours, evaluation time negligible

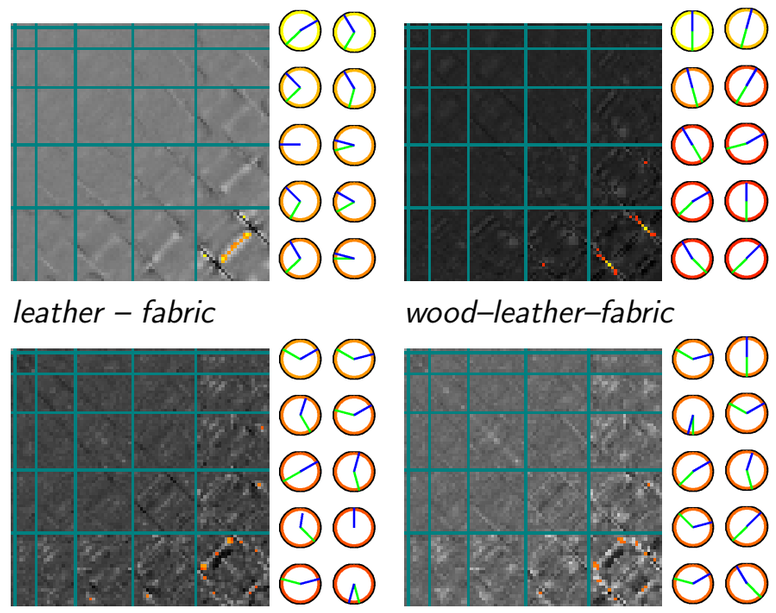
Results

- Weights of the first ten DAF features



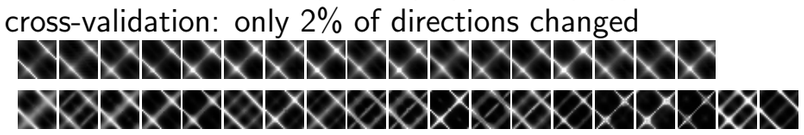
- Importance of directions for separability of categories:

wood – leather *wood – fabric*



leather – fabric *wood–leather–fabric*

- Stability experiment (wood (17)–fabric (19)) using cross-validation: only 2% of directions changed



Conclusions

- Material category (fabric/leather/wood) can be classified using a sparse set of samples near specular and anisotropic highlights.
- 10 gray-scale reflectance features are enough to keep classification accuracy $> 95\%$
- Stability of the selected bidirectional samples is very high – no significant dependency on any particular material in the test dataset.
- Advantage where taking many bidirectional reflectance samples is prohibitive.