Reflectance Analysis of Natural Images

Research at the Chair of Pattern Recognition

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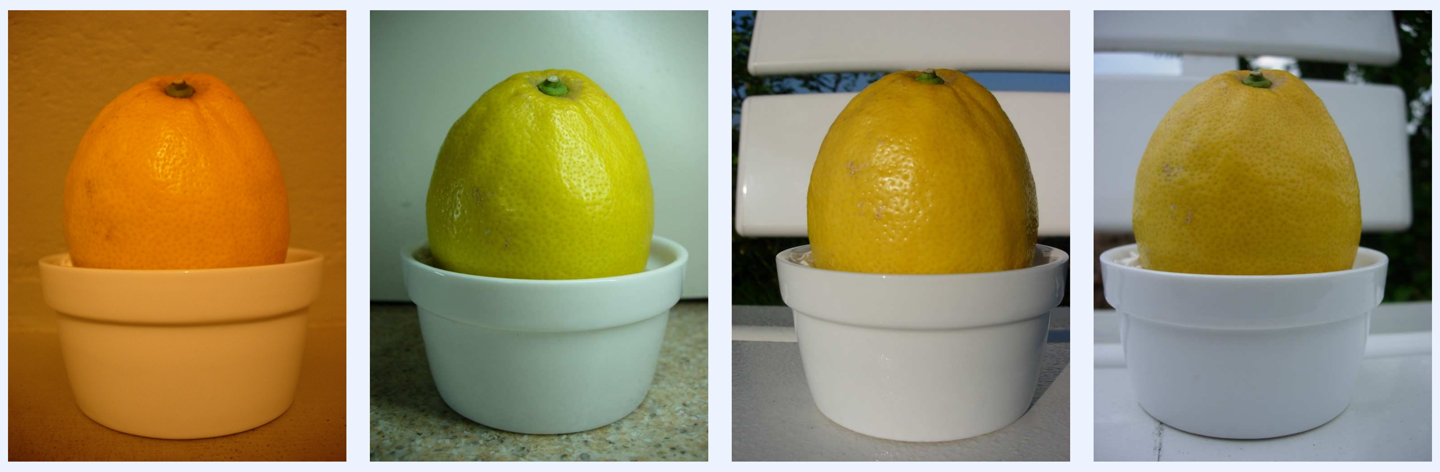
Motivation



(a) (b) (c) (d)

Figure 1: Lemon and white cup under different illuminants: (a) Tungsten light bulb, (b) halogen light bulb, (c) sun light, (d) no direct sunlight.

Knowledge about illuminant color useful for

- Compensation of appearance variations of objects
- Illuminant color as cue for image semantics

Illuminant estimation techniques often based on image specularities

- *Dichromatic Reflectance Model:* Reflected color is a linear combination of diffuse and specular reflectance
- *Neutral Interface Assumption:* Color of illuminant = color of specularities
- **But:** Segmentation of specularities is very challenging!

Segmentation of Specularities

(a) (b) (c) (d)

Figure 2: Example for a specularity segmentation algorithm (segmentation: green, generated with [5]): (a) original image (b) properly segmented pixels (c) wrongly segmented pixels (d) missed specular pixels.

Detection of specularities performs well in

- Known scene geometry
- Small number of materials and albedos

Specularity segmentation on unconstrained images is ill-posed (Figure 2, [6])

- Differentiation from bright diffuse regions
- Multiple and/or colored light sources, interreflections

Possibilities for overcoming these drawbacks

1. Improve segmentation of specularities
2. Avoid segmentation of specularities

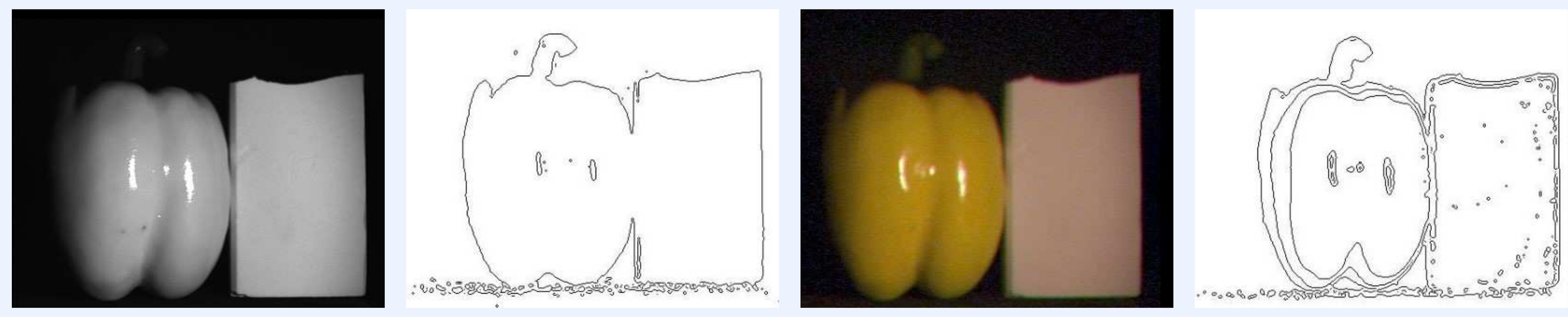
1. Improved Specularity Segmentation

Spectral Gradient [1]

- Image intensity $I(\boldsymbol{p},\lambda)$ at position $\boldsymbol{p}$ for wavelength λ depends on the illumination spectrum $e(\lambda)$, the direction of the illumination $E(\boldsymbol{p})$, and the surface reflectance $S(\boldsymbol{p},\lambda)$: $\quad I(\boldsymbol{p},\lambda) = e(\lambda)E(\boldsymbol{p})S(\boldsymbol{p},\lambda)$
- Spectral gradient of specular pixels: $\quad L_\lambda(\boldsymbol{p},\lambda) = \frac{\partial \ln(I(\boldsymbol{p},\lambda))}{\partial\lambda} \approx \frac{F_\lambda(\boldsymbol{p},\lambda)}{F(\boldsymbol{p},\lambda)} + \frac{c}{e(\lambda)}$
- Assumption: Cook-Torrance model for specularities
- At specularities: gradient primarily a function of the Fresnel term $F(\boldsymbol{p},\lambda)$

Results

- Segmentation of the spectral gradient image
- Promising results on multispectral data (Figure 3)
- Further analysis of performance on RGB data needed



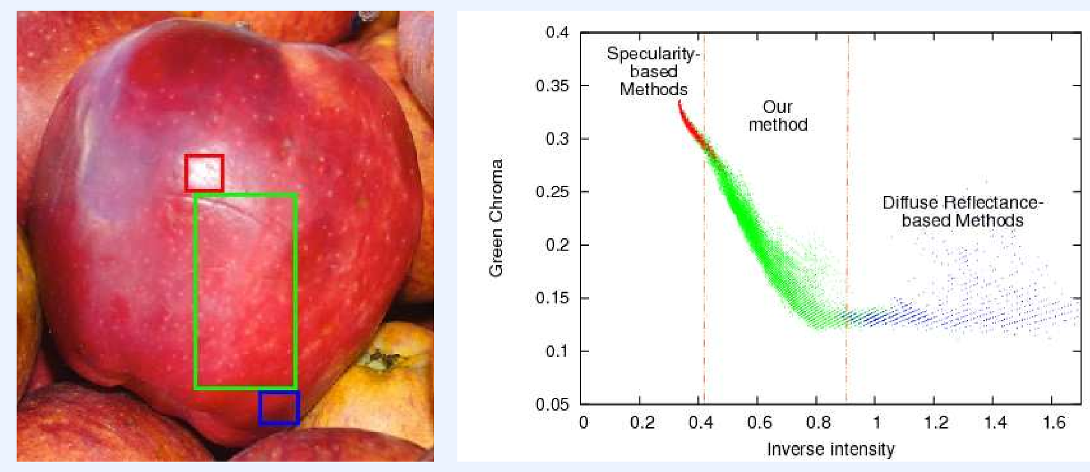
(a) (b) (c) (d)

Figure 3: Segmentation of specularities based on spectral gradients. Results of multispectral data ((a) and (b)) and RGB data ((c) and (d)).

2. Estimation of the Illuminant Color without Segmentation

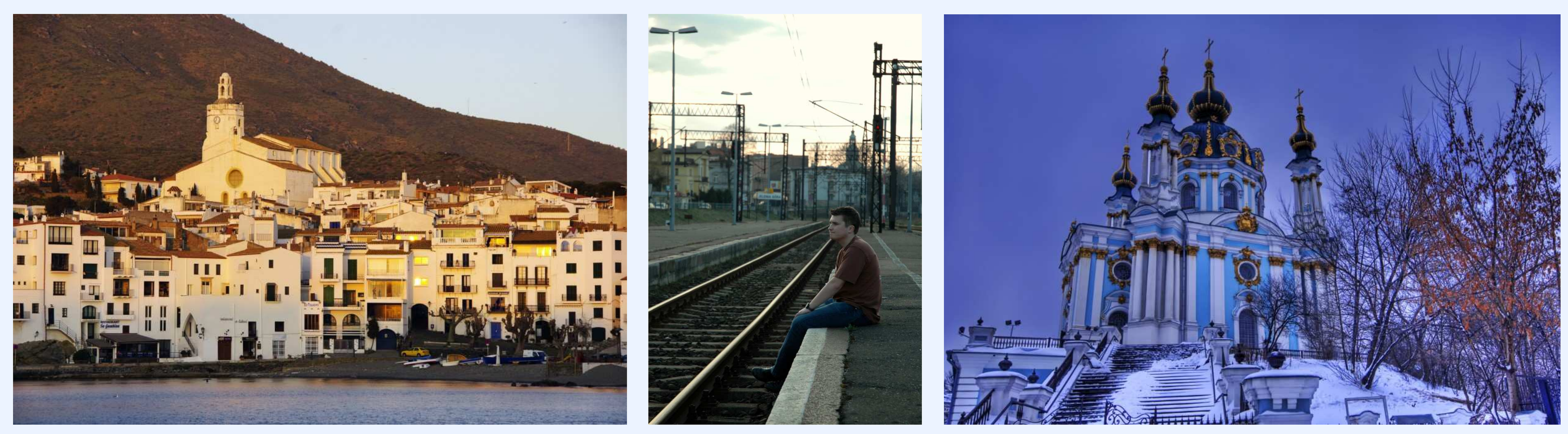
Idea: Use pixels exhibiting a mixture of specular and diffuse reflectance instead of purely specular pixels (Figure 4, [3])

- Analysis of the distribution of pixels in inverse-intensity chromaticity space [7]
- Average angular error of $8.86\,^\circ$, computed on a benchmark data set [2]



(a) (b)

Figure 4: Illumination estimation techniques based on the dichromatic reflectance model. (a) Purely specular pixels (red), mixture of diffuse and specular reflectance (green), and purely diffuse reflectance (blue). (b) Our method is based on pixels exhibiting a mixture of diffuse and specular reflectance.



(a) (b) (c)

Figure 5: Results of our illumination estimation. For each image [4] the chromaticity vector Γ of the illuminant is listed. (a) Town: $\Gamma = (0.389, 0.349, 0.261)^T$, (b) stadium: $\Gamma = (0.344, 0.338, 0.318)^T$, (c) castle: $\Gamma = (0.283, 0.325, 0.392)^T$.

Future Research Directions

In the future the following topics will be addressed:

- Improvement of specularity segmentation
- Improvement of illuminant color estimation
- Continuation of work on skin reflectance analysis: bringing knowledge from multispectral data to RGB data
- Incorporation of reflectance properties into image forensics

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References

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