Evolutive Parametric Approach for Specular Correction

Based on the Dichromatic Reflection Model

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Outline

Introduction

- The framework of this work the design of a multirobot system.
- We take the point of view of a monitoring system of the global multirobot system.
- The robot work is in outdoor environment, therefore the illumination conditions will vary slowly depending of weather conditions.
- The multirobot system task is the washing of ship holds. In this context most surfaces in the environment will be wetted.
  - The shines are a good descriptor of physical scene structure
  - The specular component is important in an image normalization process.
- We propose an approach to estimate the image specular component based on the Dichromatic Reflection Model and the Legendre polynomials.

Outline

Estimating a Specular Field

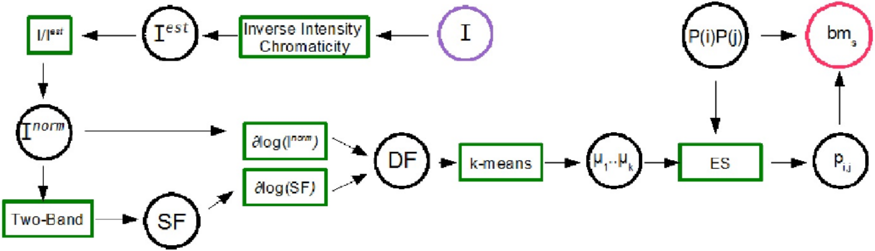


Fig. 1. Flow diagram showing the bm_s. estimation process

- Inverse Intensity Chromaticity [3]

Using the Specular Field

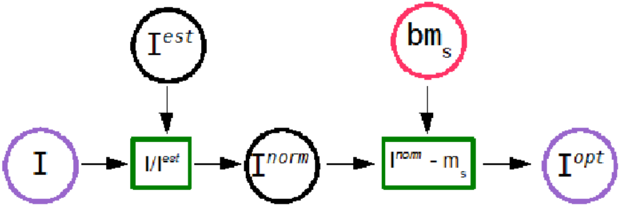


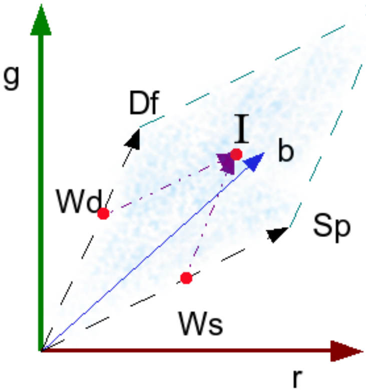
Fig 2. Illumination correction of an image using the specular field bm_s

Outline

Dichromatic Reflection Model

- The dichromatic reflection model was proposed by Shafer [1]
- The dichromatic reflection model describes the surface reflection of light in dielectric materials as the sum of two components, the **diffuse** and **specular** terms.
- The **diffuse reflection** component exhibits the color of the material. Different light wavelengths are more or less absorbed as light is scattered by the material.
- The **specular reflection** component is essentially determined by the color of incident light.

Dichromatic Reflection Model



Chromaticity Space for DRM

Normalized RGB (r + g + b = 1)

Df	Diffuse component
Sp	Specular component
Wd	Weighting factor of Df
Ws	Weighting factor of Sp
I	Sample Intensity value

Model of the image taken with a digital camera

$$I(x) = w_d(x)\int_{\Omega} S(\lambda,x)E(\lambda)q(\lambda)d\lambda + w_s(x)\int_{\Omega} E(\lambda)q(\lambda)d\lambda \quad (1)$$

$$I(x) = w_d(x)B + w_s(x)G \quad (2)$$

- $I = \{I_r, I_g, I_b\}$ is the color of an image pixel obtained through a camera sensor.
- $x = \{x, y\}$ are the two dimensional coordinates of the pixel in the image.
- $q = \{q_r, q_g, q_b\}$ is the three element vector of sensor sensitivity.
- $w_d(x)$ and $w_s(x)$ are the weighting factors for diffuse and specular components, respectively. They depend on the geometric structure at location x.
- $S(\lambda, x)$ is the diffuse spectral reflectance.
- $E(\lambda)$is the illumination spectral power distribution function, it is independent of the spatial location x because we assume a uniform illumination color.

Outline

Chromaticity

Normalized RGB

$$\sigma(x) = \frac{I(x)}{I_r + I_g + I_b} \quad (3)$$

Diffuse Chromaticity

$$\Lambda(x) = \frac{B(x)}{B_r + B_g + B_b} \quad (4)$$

Specular or Illumination Source Chromaticity

$$\Gamma = \frac{G}{G_r + G_g + G_b} \quad (5)$$

Image written in terms of chromaticity

Image model expressed in terms of chromaticity

$$I(x) = m_d(x)\Lambda(x) + m_s(x)\Gamma \quad (6)$$

Where $m_d(x) = w_d(x)\left[B_r(x) + B_g(x) + B_b(x)\right]$ and $m_s(x) = w_s(x)\left(G_r + G_g + G_b\right)$

- We can see that the diffuse chromaticity depend of location x, however the specular chromaticity doesn't depend on location x because we assume a uniform illumination color, and both weighting factors depend on the geometric structure at location x.
- In addition, from their definitions we can obtain:

$$(\sigma_r + \sigma_g + \sigma_b) = (\Lambda_r + \Lambda_g + \Lambda_b) = (\Gamma_r + \Gamma_g + \Gamma_b) = 1$$

Outline

Normalization

- The specular component must be pure white ($\Gamma_r = \Gamma_g = \Gamma_b$)
- This process requires the value of Γ^{est}

Normalized Image

$$I'(x) = \frac{I(x)}{\Gamma^{est}(x)}$$

$$I'(x) = m'_d(x)\Lambda'(x) + \frac{m'_s(x)}{3} \quad (7)$$

Renormalization

$$m_d(x)\Lambda(x) = [m'_d(x)\Lambda'(x)]\Gamma^{est} \quad (8)$$

$$m_s(x)\Gamma = \left[\frac{m'_s(x)}{3}\right]\Gamma^{est} \quad (9)$$

Outline

Specular-Free Two-Band Image Generation

$$I'(x) = m'_d(x)\Lambda'(x) + m'_s(x)/3$$

$$\tilde{I}(x) = min\{I'_r(x), I'_g(x), I'_b(x)\}$$

$$\tilde{\Lambda}(x) = min\{\Lambda'_r(x), \Lambda'_g(x), \Lambda'_b(x)\}$$

$$\tilde{I}(x) = m'_d(x)\tilde{\Lambda}(x) + \frac{m_s}{3} \quad (10)$$

Specular-free two-band [4]

$$I^{sf}(x) = I'(x) - \tilde{I}(x) = m'_d(x)\left[\Lambda'(x) - \tilde{\Lambda}(x)\right] \quad (11)$$

Outline

Diffuse Regions

- We can find diffuse regions which have some properties:
  1. Two neighboring pixels have the same chromaticity
  2. We detect and reject color border pixels
  3. We detect and reject noise pixels
- Under this assumptions we can find diffuse pixels, and the rest must be specular pixels

Separation Method

A diffuse pixel in a normalized image

$$I'(x) = m'_d(x)\Lambda'(x) + m'_s(x)/3$$

$$I'(x) = m'_d(x)\Lambda'(x)$$

$$I'(x) = m'_d(x)\Lambda'$$

$$log(I'(x)) = log(m'_d(x) + log(\Lambda'))$$

$$\frac{\partial}{\partial x} log(I'(x)) = \frac{\partial}{\partial x} log(m'_d(x))$$

A pixel in a Specular Free Image

$$I^{sf}(x) = m'_d(x)\Lambda^{sf}(x)$$

$$I^{sf}(x) = m'_d(x)\Lambda^{sf}$$

$$log(I^{sf}(x)) = log(m'_d(x) + log(\Lambda^{sf}))$$

$$\frac{\partial}{\partial x} log(I^{sf}(x)) = \frac{\partial}{\partial x} log(m'_d(x))$$

Separation Method

The method is based on the difference of the image logarithm differentials

$$\triangle(x) = dlog(I'(x)) - dlog(I^{sf}(x)) \quad (12)$$

if $\triangle(x)$= 0, then is a diffuse pixel

Outline

Energy Function

We are adapting the ideas about intensity inhomogeneity correction in MRI [2] to our problem.

Energy Function

$$E_{tot} = \sum_{x \in I^{norm}} \left(I^{norm}(x) - bm_s(x,p) - \mu_k(x) \right)^2 \quad (13)$$

$$bm_s(x,p) = \sum_{i=0}^{l} \sum_{j=0}^{l} p_{i,j} P(i) P(j)$$

Evolutionary algorithm goal

The evolutionary algorithm must look for the correct Legendre polynomial parameters, to find a good approximation to the Specular field bm_s

Outline

The experiment

- The picture was taken in a real ship hold.
- There are two workers. They wear clothes of color similar to the floor, and they are in a shine region.
- We try to reduce the reflections to obtain a corrected image.
- In the corrected image we can find easily the workers.
- The corrected images add robustness to system.

Outline

Normalized, Bias and Corrected

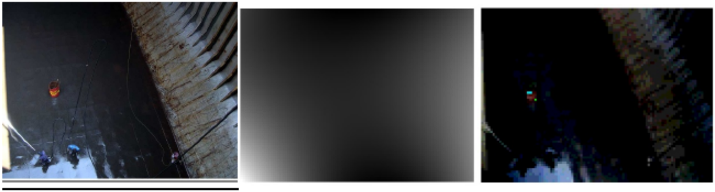


Fig. 3. From left to right: Original image, the estimated specular bias bm_s composed of polynomials of degree up to 2, and the corrected image obtained removing the specular bias

Bias and Corrected

Fig 5. Left image: estimated specular field in the region of the workers. Right image: corrected removing the specular field.

Saturation for region differentiation

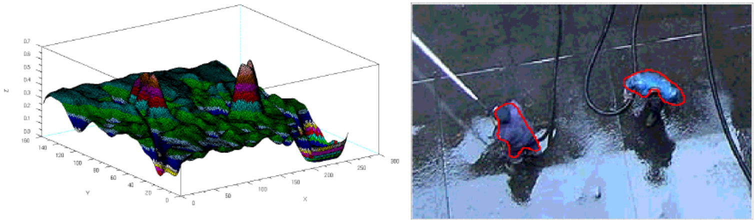


Fig. 6. Left image, map of the color saturation in HSV color space for image. Right image: identification of the workers performed thresholding the saturation image.

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Thank you!!