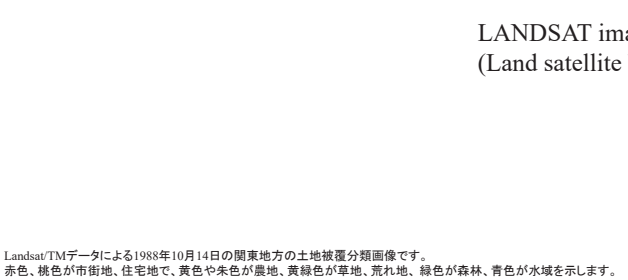
光画像工学
Optical imaging and image processing
(XI)

5. Multispectral imaging

5.1 What is multispectral imaging
- Satellite image, remote sensing
- Object discrimination, target detection
- Color reproduction

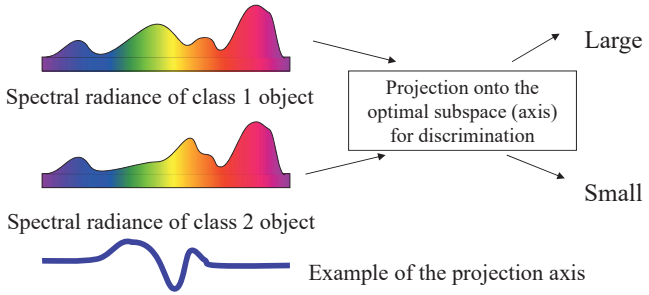
LANDSAT image
(Land satellite by US)



Landsat/TMデータによる1988年10月14日の関東地方の土地被覆分類画像です。
赤色、桃色が市街地、住宅地で、黄色や朱色が農地、黄緑色が草地、荒れ地、緑色が森林、青色が水域を示します。

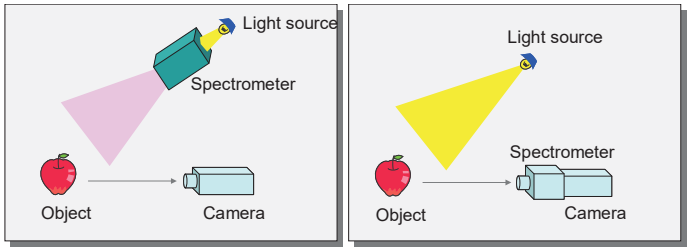
Object recognition using multispectral images

- Multispectral image acquisition
- Statistical classification of spectral data
  - Linear classification, PCA, ICA (independent component analysis), Canonical discriminant analysis
- Optimal design of the spectral sensitivities of imaging systems
  - Color imaging can be considered as the projection in the spectral space



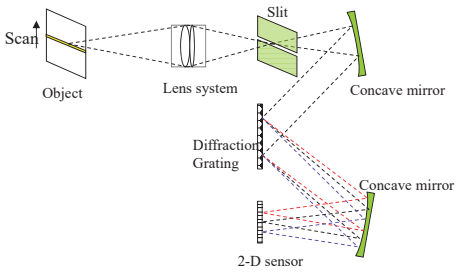
5.2 Methods for spectral imaging

Location of dispersive element or spectral filter	Bandwidth	Acquisition methods	Optical device
Between object and sensor Between illuminant and object	•Narrow •Wide	•Point sequential •Line sequential •Band sequential •Mozaic filter •Others	•Diffraction grating •Interference filter •Absorption filter •Dichroic prism •Fourier transform spectroscopy •Emission •Others



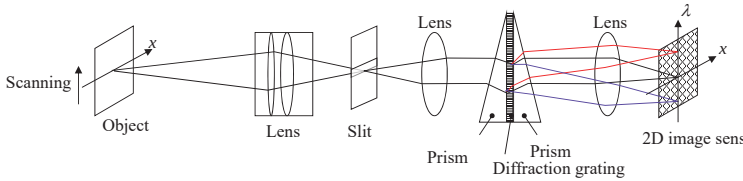
(a) (b)

Spectral imaging device using diffraction grating



Spectral data of a line can be acquired; a spectral image is captured with scanning of the object or the optical system.

The optical system for direct vision spectral imaging
(Grism: Grating-Prism, PGP: Prism-Grating-Prism)



ref. Finland, Specim http://www.specim.fi/

Spectral imaging device using absorption filter

Fig. 1. Camera system for multichannel imaging.

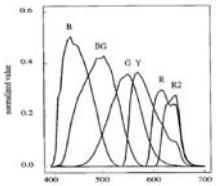
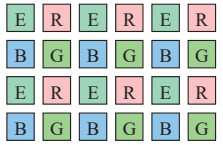


Fig. 4. Spectral-sensitivity functions for the six sensors. R, red; B, blue; G, green; Y, yellow.

The system for
6-band image capture*1)

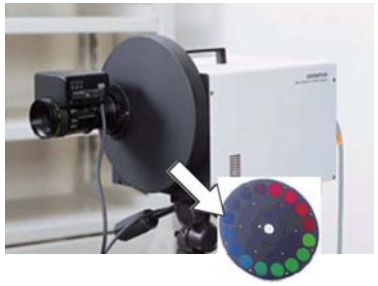


4-color filter DSC*2)

Wider bandwidth
Spectral reconstruction is required → S/N decreased
Optimization of spectral sensitivity is important

*1) S. Tominaga, J. Opt. Soc. Am. A Vol. 13, No. 11/November 1996/ 2163-2173
*2) 加藤直哉, 日本写真学会誌, Vol.67別冊1, pp.14-16 (2004)

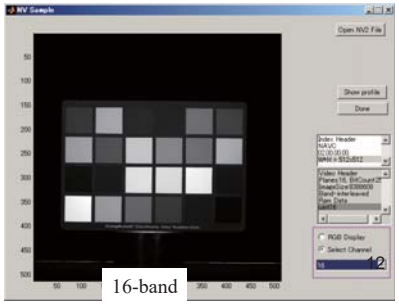
Spectral imaging device using interference filter



16-band filter-wheel multispectral camera
(TAO/NICT, Japan)

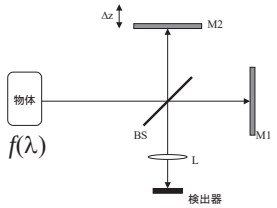
16-band image

Color reproduction



16-band

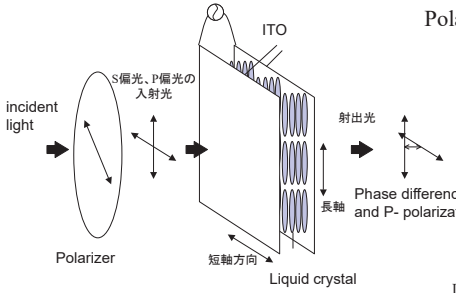
Spectral imaging device using Fourier transform spectroscopy



Michelson interferometer

$$\text{Sensor output} \propto \int \frac{f(\lambda)}{2}\{1+\cos(\frac{2\pi}{\lambda}\Delta z)\}d\lambda$$

Polarization interferometer using liquid crystal



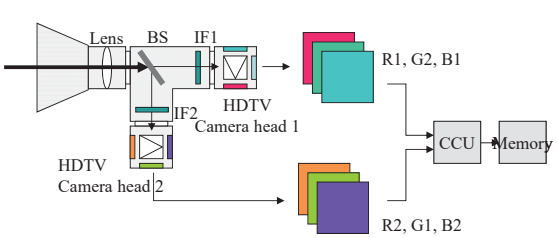
Liquid crystal device modulates optical path difference Δz

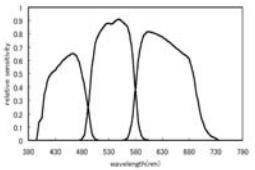
Stacking multiple layers for narrow-band transmission characteristics

Liquid Crystal Tunable Filter: CRi Inc., http://www.cri-inc.com/

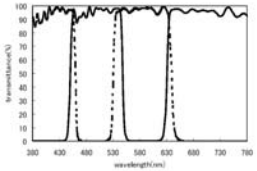
Spectral imaging device using hybrid method

- 6-band HDTV camera (NICT)

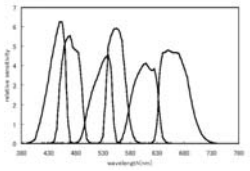




Spectral sensitivity of 3-and camera



Spectral transmittance of filters IF1 and IF2



Spectral sensitivity of 6-band camera

Ref. K. Ohsawa, T. Ajito, et. al., J. Imag. Sci. and Tech., Vol.48, No.2; pp.85-92 (2004)

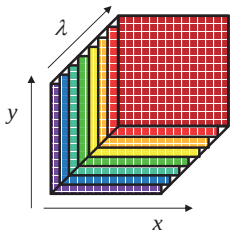
5.3 Multispectral imaging for color reproduction
Why RGB Imaging is not enough?

- RGB does not represent the color attribute of an object.

- Spectral sensitivity of conventional color imaging device is not equivalent to human vision
- Color reproduction under different illumination environment
- Is not "Quantitative" information for image analysis
- The color gamut of display does not cover all the existent colors
- Observer Metamerism: Color matching for different observers

Single-shot spectral imaging
Computational spectral imaging

$$g_k = \int \int \int f(x,y,\lambda)\, h_k(x,y,\lambda)\, dx\, dy\, d\lambda \qquad (1)$$



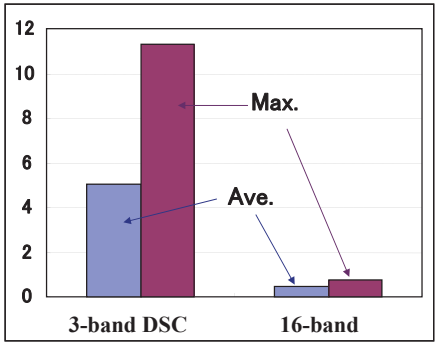
$f(x,y,\lambda)$

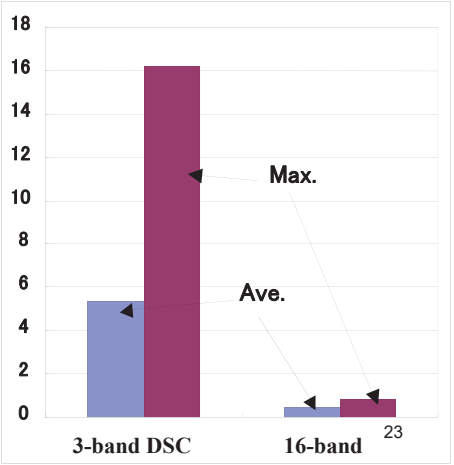
Spectral data cube

Accuracy of color estimation

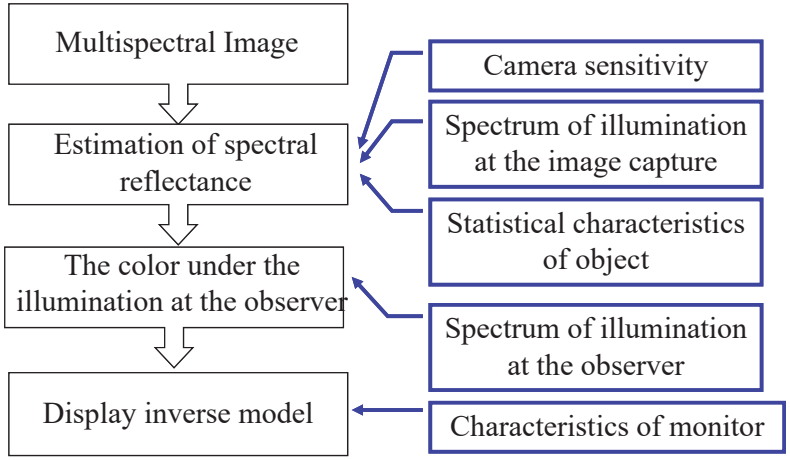
- CIELAB color difference of GretagMacbeth ColorChecker (24 color patches) - Experimental results

Illuminant:
Capture=D65, Reproduction=F2 →
Capture = Reproduction = D65↓

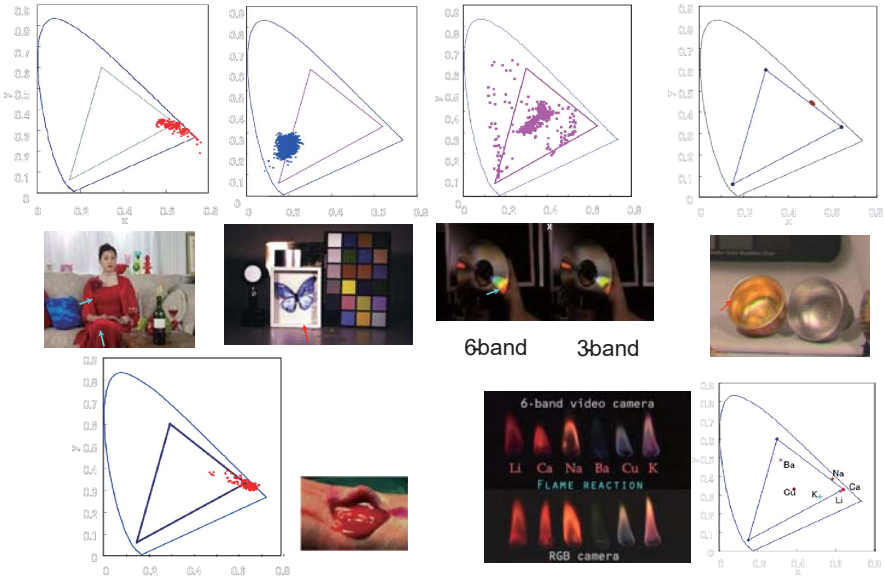


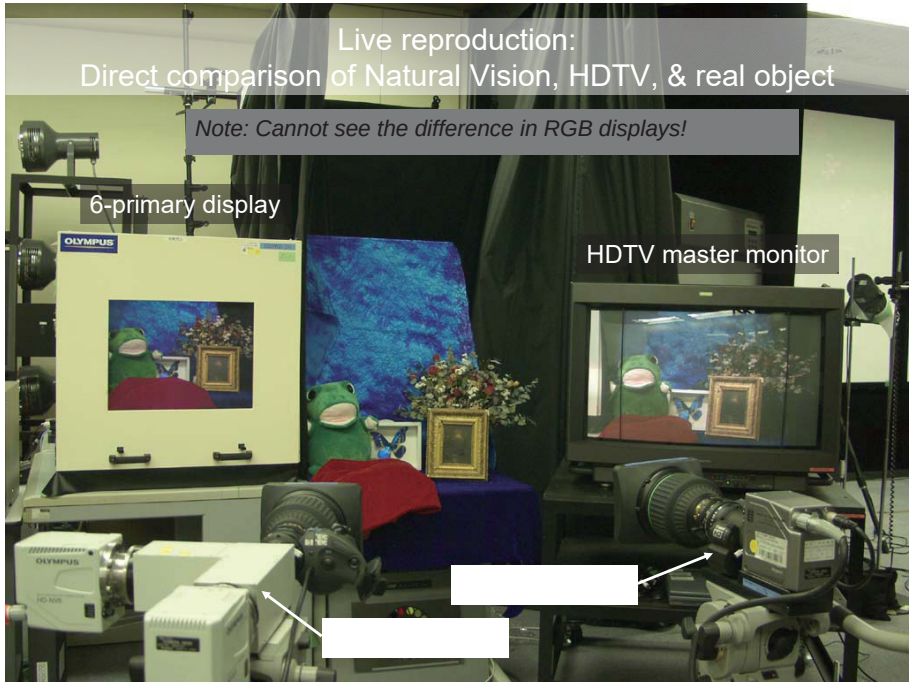


Spectrum-based Color Reproduction Algorithm



High chroma colors captured by 6-band camera





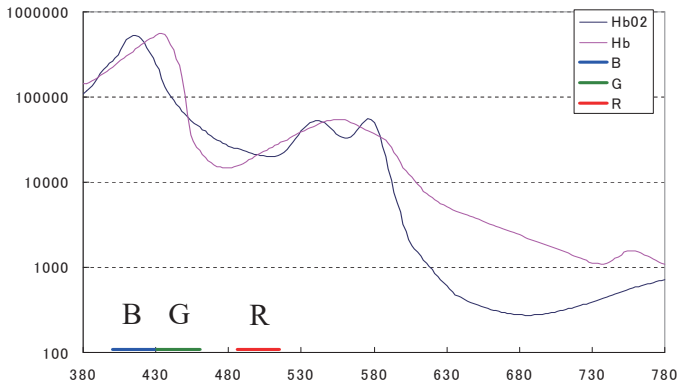
5.4 Applications of multispectral imaging

- Medicine
  - Dermatology, Pathology, Endoscopy (ex. Narrow band imaging),
  - Dentistry, Telemedicine, Surgery, Ophthalmology
- Printing
  - Image acquisition for merchandize catalog printing
- Electronic commerce
  - Textile: Hi-fi color reproduction, expanded color gamut
  - Virtual prototyping by multispectral BRDF measurement and multispectral rendering
- Digital archive, digital museum
  - Multispectral image archive of artworks and cultural heritage
  - Reproduction of woodprints by Shiko Munakata
  - Capture and reproduction of natural scene, ex., Aurora
- CG
  - New expression in computer graphics
  - Spectral rendering

Imaging of artworks, cultural heritages: digital archives

- デバイスや照明光に依存しない正確な色を保存
- 忠実な色を持つ複製の作成
- ディスプレイ上での鑑賞
  - 異なる照明環境下での色の見えのシミュレーション
- 修復
  - 皮膜除去、修復のシミュレーション
  - 色材の推定
- 分析
  - 色材の分析、補修跡の検出、退色の分析、紙質の分析…

Color image by narrow-band light



Demonstration experiment

-- Simulated clinical consultation through NV system --

Patient

Manabeshima

Doctor

Kasaoka Daiichi Hospital

Doctors in the Hospital consulted the simulated patient in the clinic through NV teleconference system.

6-band NV video of HD format transmission through H.264 codec and the Internet. Doctors observe the images on the 46” LCD.