THE POLARISATION OF LIGHT

MAKING HIDDEN THINGS VISIBLE

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AGENDA

Basics of Polarisation
  • Types of polarisation
  • Stokes parameter, degree of linear polarisation, angle of polarisation

Polarisation Imaging Technology
  • Area polarisation camera
  • Line scan polarisation camera

Polarisation Analysis with Stemmer Imaging
  • CVB Polarisation
  • Applications
POLARISATION – BASICS

Physical Properties of Light

- **Intensity**: amount of photons \(\Rightarrow\) brightness
- **Wavelength**: energy \(\Rightarrow\) color
- **Polarisation**: direction of electromagnetic field vector

\(\Rightarrow\) not visible by the naked eye
POLARISATION – DIFFERENT TYPES

How does (polarised) light occur?

- Unpolarised Light
- Linear polarisation
- Circular polarisation
- Elliptical polarisation

Unless stated otherwise, polarised light is linearly polarised (also known as plane polarisation).

If the two fields are 90 degrees (a quarter wavelength) out of phase, the sum traces a circle around the axis... like a corkscrew!
Polarised Sunglasses

- Vertical polarisation axis
- Eliminates most of the partly horizontally polarised light
**POLARISATION – MATHEMATICAL DESCRIPTION**

**Physical Description of the (linear) Polarisation**

- Stokes vector
- Stokes parameter
- Degree of linear polarisation:
  
  \[
  \text{DoLP} = \frac{\sqrt{s_1^2 + s_2^2}}{s_0}
  \]

- Angle of mean polarisation:
  
  \[
  \text{AoMP} = \frac{1}{2} \cdot \arctan \left( \frac{s_2}{s_1} \right)
  \]
Polarisation by Reflection

How do we get polarised light by reflection?

- Reflection: component perpendicular to plane of incidence (s-state) is strongly reflected
- Brewster angle: component parallel to plane of incidence (p-state) is purely transmitted, highest contrast
AREA SCAN SENSOR WITH INTEGRATED POLARISATION FILTERS

Sensor: SONY IMX250MZM POL

- Specifications:
  - 2448 x 2048 Pixel, 3.45 μm, 2/3"
  - 22 fps

- Integrated polarisation filter array:
  - Nano wire technology
  - 90°, 45°, 135°, 0° orientations
  - High contrast in visible spectrum/NIR
  - Subsampling/Interpolation necessary ⇒ reduced resolution

Attention!
Nanowire orientation ≠ transmitted polarisation
LINE SCAN SENSOR WITH INTEGRATED POLARISATION FILTERS

Sensor: Teledyne Dalsa Quad-linear Line Scan Sensor

- Specifications:
  - 2048 x 4 Pixel, 7.04 µm,
  - 70 kHz
  - CameraLink interface

- Integrated polarization filters:
  - Nanowire technology
  - 0° (R), 90° (G), 135° (B) orientation
    + unfiltered state (mono)
  - \( I_{0°} + I_{90°} = I_{45°} + I_{135°} \)
  - High contrast in visible spectrum
  - Full 2k resolution in every orientation
POLARISATION ANALYSIS – WHAT DO WE NEED?

„Hey let’s try a polarisation camera!“

„I want to check my ruler!“

Customer
POLARISATION ANALYSIS – WHAT DO WE NEED?

„Looks like a monochrome image“

Customer

!?
POLARISATION ANALYSIS – CVB POLARISATION

Which pictures do we calculate out of the RAW image?

- Stokes parameter:
  - $S_0 = I_{0°} + I_{90°}$ overall intensity
  - $S_1 = I_{0°} - I_{90°}$
  - $S_2 = I_{45°} - I_{135°}$

- Degree of (linear) polarisation: $DoLP = \frac{\sqrt{S_1^2 + S_2^2}}{S_0}$
  - Completely polarised $\Rightarrow$ DoLP = 1
  - Completely unpolarised $\Rightarrow$ DoLP = 0

- Angle of polarisation: $AoMP = \frac{1}{2} \cdot \arctan\left(\frac{S_2}{S_1}\right)$

- False color representation in HSV colorspace
  - Hue: angle of polarisation
  - Saturation: degree of polarisation
  - Value: $S_0$
POLARISATION ANALYSIS – POSSIBLE APPLICATIONS

- Reducing reflections/glare

- Determination of the orientation of reflecting surfaces
  - Alignment of metal filaments or carbon fibers

- Material discrimination
  - Difference in degree of polarisation (diffuse ↔ specular)
  - Rotation of angle of polarisation (optically active)

- Detection of impurities (oil films, etc.)

- Stress in glass and plastic
POLARISATION ANALYSIS – POSSIBLE APPLICATIONS

Birefringence/Stress
POLARISATION ANALYSIS – POSSIBLE APPLICATIONS

Film/Foil Inspection

HSV

HSV

HSV
POLARISATION ANALYSIS – POSSIBLE APPLICATIONS

Reduction of Reflections

Intensity Images $I_{0^\circ}$ $I_{90^\circ}$ $I_{45^\circ}$ $I_{135^\circ}$
POLARISATION IMAGING – HOW CAN STEMMER HELP?

“Work together with Stemmer Imaging!“
THANK YOU FOR YOUR TIME

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