Disclaimer

This summary is part of the lecture "ETH Image Analysis & Computer Vision" by Prof. Van Gool, Prof. Konukoglu and Prof. Goksel (HS19). It is based on the lecture slides and script.

Please report errors to doberm@student.ethz.ch such that others can benefit as well.

The upstream repository can be found at https://github.com/mrrebod/Summaries

Image Analysis & Computer Vision

Marco Dober

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1 Introduction

Vision is important:

- Half our brain is devoted to it
- Developed many times douring evolution
- It is non-contact
- It can be implemenmted with high-resolution
- Works with ambient EM-waves
- yields color, texture, depth, motion, shape

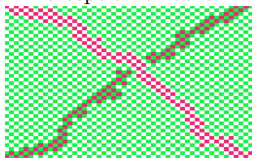
Take home message:
For people vision is their most crucial sense, for good reason

1.1 Perception of vision

Perception of **intensity**

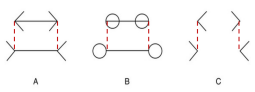
The gray fields have the same intensity (same gray tone).

Perception of **color**



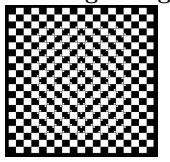
The red squares have equal color

Perception of **length**



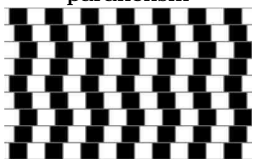
the horizontal lines are equally long.

Lines being straight



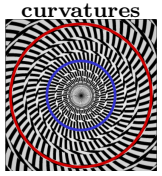
The lines do not have any curvature

Perception of **parallelism**



All lines are parallel.

Perception of **curvatures**



There is no spiral.

Perception of **motion**

The pole rotates about the vertical, it does not translate vertically.

The role of **context**

All encircled patterns are identical!

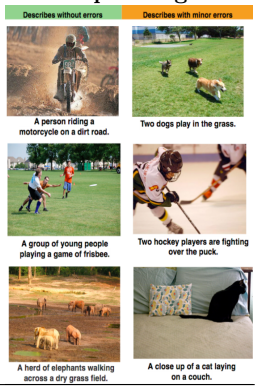
Take home message:
Effective vision needs more than sheer filtering and measuring

1.2 Applications

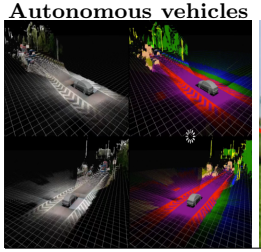
Most early applications where found in **production environments**, as these allow for **controlled conditions** and have **little uncertainty**. But some areas do not allow for much control: medical IP, remote sensing, surveillance, etc.
Currently Computer Vision (CV) is conquering the less controllable areas by storm:

Image enhancement:
mobile → DSLR

Image retrieval, captioning

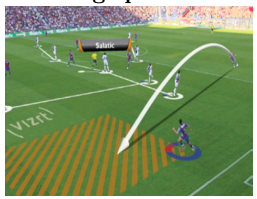


Autonomous vehicles



Visual surveillance

Augmented Reality, e.g sports



Computer-assisted surgery

Take home message:
It is feasible now to let most things see and interpret their environment.

1.3 The nature of light

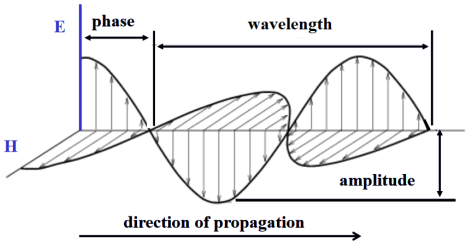
There are three different models to describe optical systems:

1. Geometrical optics
2. Physical optics → **wave character**
3. Quantum-mechanical optics

In this course we mainly look at physical optics and the wave character of light.

1.3.1 Light as EM-waves

Self-sustaining exchange of electric and magnetic fields. An EM-wave is characterized with the following properties:

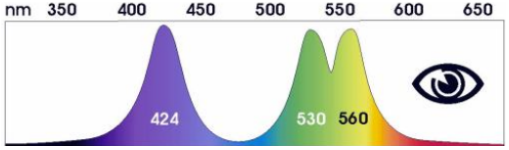


- **Wavelength**
- Direction of **propagation**
- **Amplitude** of E
- **Phase**
- Direction of **polarization**

The spectrum:
Normal ambient light is a mixture of wavelengths, polarization directions and phases. The visible range for humans is only a small fraction of the EM-waves-spectrum.

Wavelength $[nm]$		Color
380 - 450	→	violet
450 - 490	→	blue
490 - 560	→	green
560 - 590	→	yellow
590 - 630	→	orange
630 - 760	→	red

The visible range differs from humans to animals and also cameras may have different spectral sensitivities. There are also cameras for non-visible light such as infrared. The following picture shows the three color cones humans have and their sensitivity range:



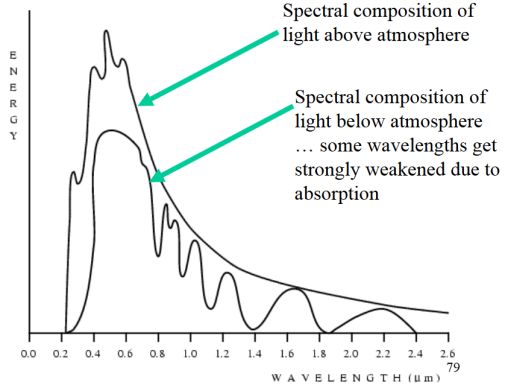
1.3.2 Interactions with matter

We look at the following types of interaction with matter:

1. **Absorption**
   → blue water
2. **Scattering**
   → blue sky
   → red sunset
3. **Reflection**
   → colored ink
4. **Refraction**
   → dispersion by a prism
5. **Diffraction**

We look at few of those in more detail:

1. Absorption
A nice example of absorption is earth's atmosphere which absorbs certain wavelengths of the incoming light. The absorbed frequencies correspond to resonance frequencies of molecules in earth's atmosphere.



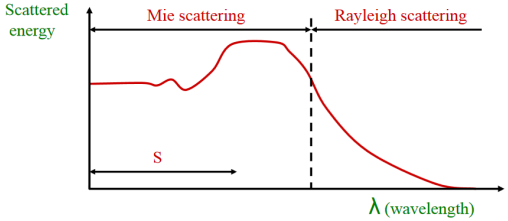
2. Scattering
There are three types of scattering depending on the relative sizes of particles and wavelengths:

(a) Small particles: **Rayleigh** (strong wavelength dependent)

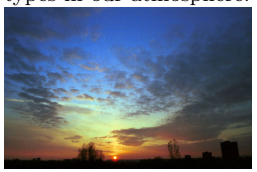
(b) Comparable size: **Mie** (weakly wavelength dependent)

(c) Large particles: **Non-selective** (wavelength independent)

If we look at the scattered energy it looks as follows:



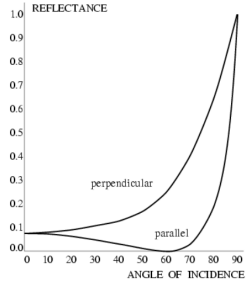
Let's see some examples of these different scatter-types in our atmosphere:



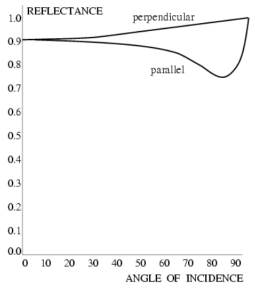
Rayleigh: Tyndall effect (blue sky, red setting sun)
Non-selective: Grey clouds

Mie: Colored cloud from volcanic eruption

3. Reflection:
In mirror reflection we have:
angle of reflection = angle of incident.
Two different categories of reflective materials:

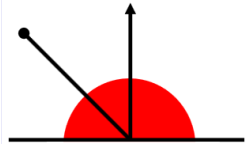


Dielectric:
For parallel polarization there exists the Brewster angle where $r = 0$.

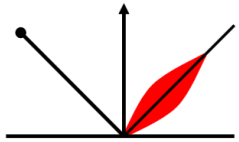


Conductor:
Strong reflectors under all angles, more or less preserve polarization.

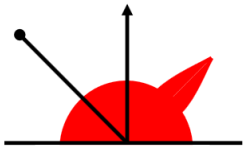
We differentiate three types of reflection which depend on the surface structure:



Diffuse:
Also called **Lambertian**. Rough surfaces.

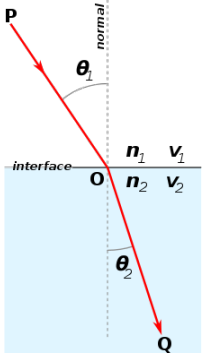


Specular:
Mirror-like surfaces.



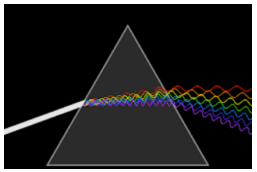
Mixed:
Mix of diffuse and specular.

4. Refraction:



Effect of the bending of light if it hits an interface of two materials with different refraction index $n = \sqrt{\epsilon\mu}$. The bending is described through **Snell's law**:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$



Dispersion:
The bending is dependent of the frequency (wavelength) of the light.

2 Image Acquisition

2.1 Illumination

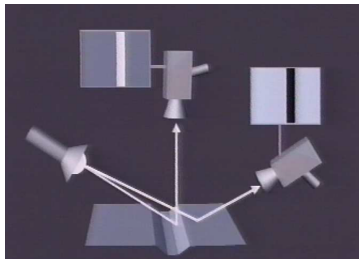
Well designed illumination often is key in visual inspection and can extremely simplify the image processing. Here is an overview of different illumination techniques:

2.1.1 Back-lighting

How:
Lamps are placed behind a transmitting diffuser plate which is located behind the object

Why:
Creates **high-contrast** silhouette images, easy to handle with **binary vision** (only two intensity levels, black and white). Often used in inspection.

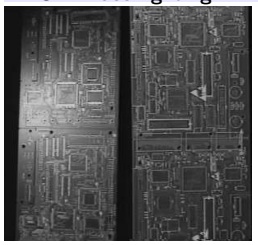
2.1.2 Directional-lighting



How:
Light source shines directly on object, maybe under a certain angle.

Why:
- Generation of **specular reflection** (e.g. crack detection (see figure above))
- Generation of **sharp shadows**

2.1.3 Diffuse-lighting



Left:
Direct lighting produced large changes in brightness due to specular reflection.

right:
Diffusive lighting reduces bright spots.

How:
Do not directly shine with light source on object, but rather indirectly with the help of a diffusive surface. It does not reduces the specular reflection, but increases the diffuse reflection component, yielding in less variations.

Why:
Prevents sharp shadows and large intensity variations over glossy surface.

2.1.4 Polarized-lighting
2.1.5 Colored-lighting
2.1.6 Structures-lighting
2.1.7 Stroboscopic-lighting

2.2 Cameras

3 Feature Extraction