Introduction to Computer Vision

KKY/USVP Lecture 1

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What is Computer Vision?

Image processing

Lower level. Image processing addresses techniques that process image in some way. e.g. noise filtration, image compression, image sharpening or basic searching for objects.

Computer Vision

Computer Vision is the science that focus on techniques that enable computer to understand high level information in digital images (scene and its 3D representation). It uses wide range of techniques such as Feedback, Modeling of the world and objects, methods from Artifical Inteligence, ...

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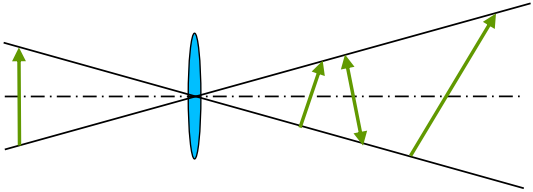
Why is it hard?

- Loss of information due to perspective projection, can be solved by using more than one camera.



- The basic unit – brightness – depends on multiple factors such as camera pose and orientation, light source properties or an object material reflectivity.
- A presence of the noise in the real world data.
- An amount of data especially in the case of video stream.
- Local window from the global view

Recognition vs. Reconstruction

Recognition

- Scene is classified objects into classes.
- Classes are usually known in advance.

Reconstruction

- Searching for the physical parameters of the scene
  - orientation
  - color
  - depth
  - light and surface properties
- Searching for a relations between objects in the scene.

Basic concepts

Image Function

- The result of perspective projection with respect to geometry of the scene.
- Usually denoted as f(x,y) or f(x,y,t)

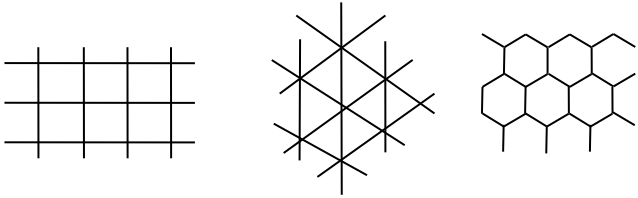
$$f(x, y, t) = \int_0^\infty e(x, y, t) \cdot S(\lambda)\, d\lambda, \tag{1}$$

where x and y are spatial coordinates of the pixel, t is a time.

- The value of the continous image function is a intensity (grayscale image) or color (color image) of the point in the scene.

Image digitization

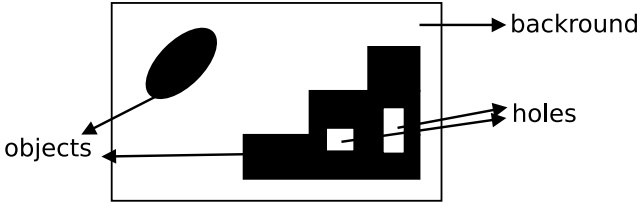
- **Sampling** – image points layout



- R**ectangular grid** can cause problems based on the different distance between points.
- **Sampling theorem** is crucial – unsufficient density of points $\Rightarrow$ aliasing.
- **Quantization** – Results of image function are quantized – usually 8 bits
- **Note** – Human eye is capable to recognize approximately 50 levels of grayscale intensity,

Basic concepts - area, object, background

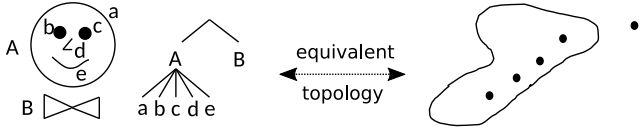
- Image can be divided into areas which belongs either to objects R_i or to the background R_c of the image:



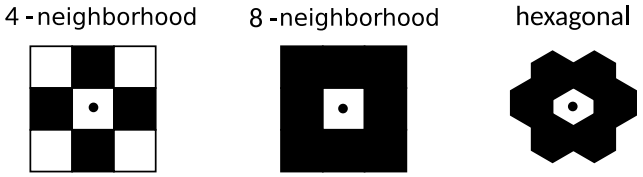
- Area – continuous set of points
- Objects – all objects $R \cup_i R_i$
- Background – R_c – can be composed from multiple parts (holes in objects)

Basic concepts - Topology, neighborhood

- Topology – arrangement of the image parts



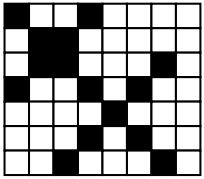
- Neighborhood



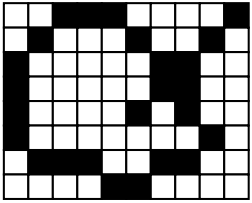
Distance and Paradoxes

- Distance between pixels
  - Euclidean $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$
  - City block $| x_1 - x_2 | + | y_1 - y_2 |$
  - Chessboard $max\,(| x_1 - x_2 |, | y_1 - y_2 |)$
- Paradoxes

line paradox



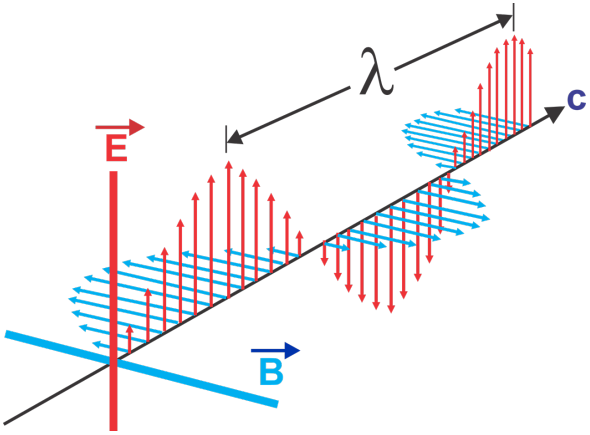
Jordans paradox



Light characteristics and Geometric Optics

Light characteristics

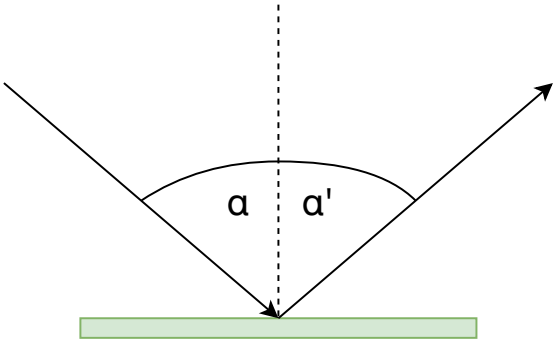
- Visible part of the electromagnetic radiation spectrum
- Electromagnetic waves
- Wave lentgh λ[m]
- Frequency $f = \frac{c}{\lambda}$ where $c \approx 3 \cdot 10^8$ m/s is the light speed
- Light intensity
  - maximum – white
  - zero – black)



Light characteristics and Geometric Optics

Surface reflection

- Occurs when light bounces off an object surface – i.e. different .
- Partial or no light penetration to the object $\Rightarrow$ reflection.
- Law of reflection: The angle α which the incident ray makes with the normal is equal to the angle α' which the reflected ray makes to the same normal.



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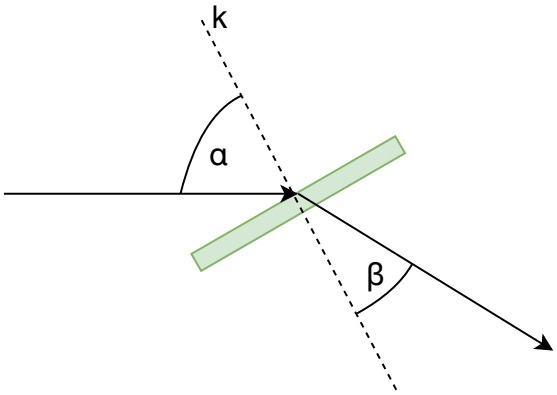
Light characteristics and Geometric Optics

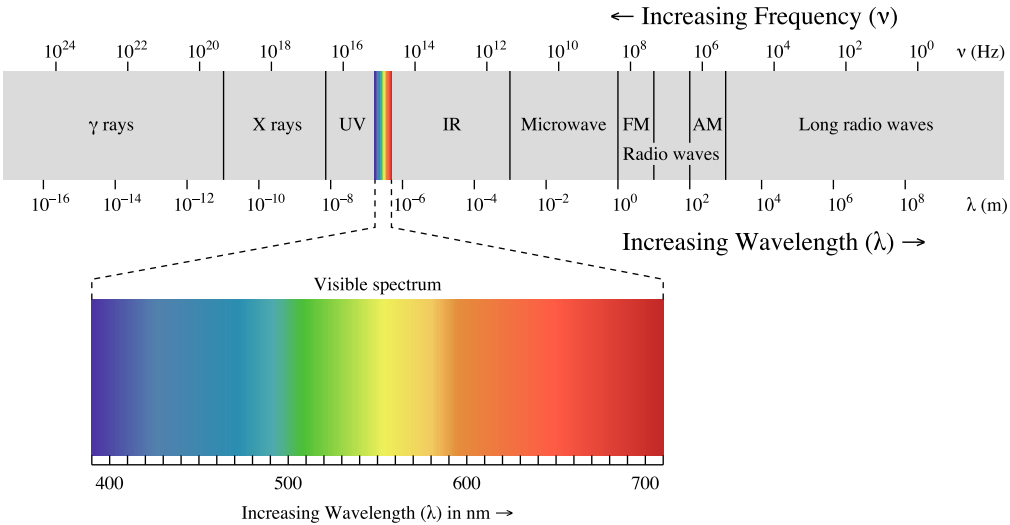
Light refraction

- Occurs when light passes into another material.
- **Refraction law:** Light falls on the surface at an incidence angle α and passes at a transmission angle β . Angle is defined as a ratio of refractive indexes n_1, n_2 of both materials:

$$\frac{sin\alpha}{sin\beta} = \frac{n_2}{n_1} \qquad (2)$$



Electromagnetic spectrum



Photographic film

Properties

- most used $\rightarrow$ 35 mm color film
- film box size $\rightarrow$ 24x36 mm
- resolution is based on the siye of the crystals
- higher sensitivity (DIN, ASA) $\rightarrow$ greater roughness of the crystals
- usually 100-200 ASA, higher sensitivity 800-1600 ASA.
- $x \cdot 100$ [ASA] $= 21 + 3 \cdot x$ [DIN]

Television

Principle and properties of the television

- transforms electric signal into images by projecting on the screen
- based on the deflected beam crossing the screen
- screen is covered by thin layer of phosphor $\Rightarrow$ phosphoresce
- phosphoresce depends on the intensity of the beam.
- Standards for color signal transimission:
  - PAL - European standard (625 rows, 50 Hz)
  - NTSC - American standard (455 rows, 60 Hz)
  - SECAM - East european standard (625 rows, 50 Hz)
  - HDTV - Current digital standard (720-1080 rows, 24-60 FPS)

The scanning pattern

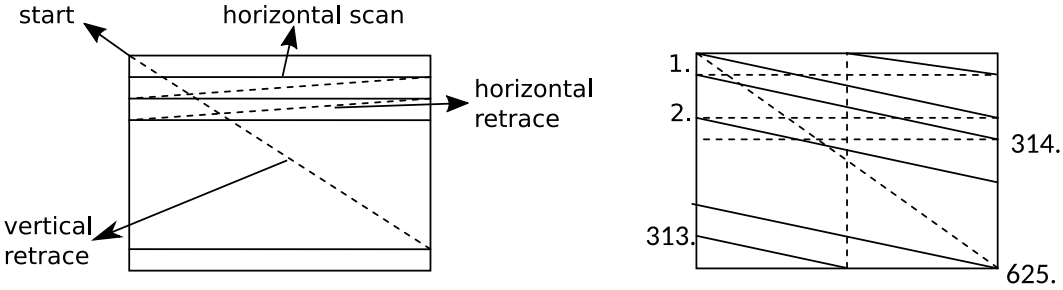


Figure: TV scanning pattern (Left), Interlaced scanning (Right)

Hardware for image digitization

Definition

Hardware for image digitization is every device which transform light radiation into matrix of numbers.

Examples

- Digital camera (Compact, Ultrazoom, Digital Single-Lens Reflex camera (DSLR))
- Industry cameras (PointGrey, Bassler, Ueye, ...)
- RGBD cameras (Intel RealSense, ZED camera, Microsoft Kinect, ...)
- Thermocameras (Flir, Optris, Workswell, ...)
- Other types of cameras (Webcams, Go Pro, ...)

Parts of the devices for image digitization

Sensor – CCD nebo CMOS

- supposed to image capture
- composed of the matrix of light sensitive elements

Shutter – mechanic or electronic

- Allows light to pass to the sensor for a set exposure time.
- mechanic shutter global or rolling
- electronic shutter is a moment in time when all time exposed sensor reads intensity values

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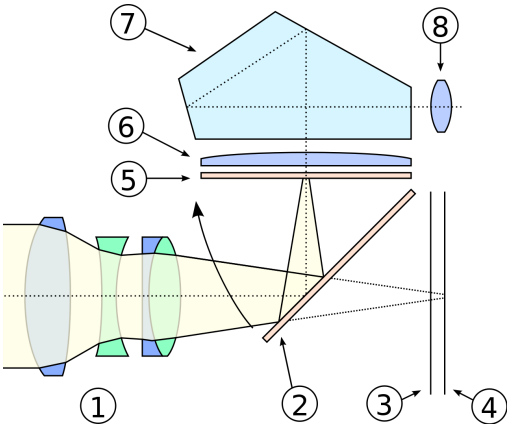
Parts of the devices for image digitization

Lens

- lens / lens system
- concentrates the rays of light on the sensor
- fixed or variable focal length
- responsible for projective transformation
- image on the right: structure of the lens system



Camera Obscura

- 1545: Reinerus Gemma-Frisius ⇒
- Box with a tiny hole.
- Light passes throught hole to the oposit side of the box and creates an image.
- Image is overturned → consequence of light pass through the hole.
- Base for the matematical model of the camera → Pinhole Camera Model

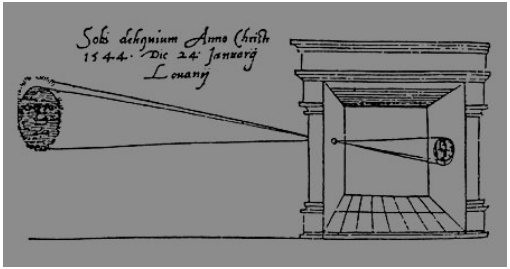


Image File Formats

bits on 1 pixel

- 1 bit – binary image
- 8 bit – grayscale image – 256 brightness levels
- 24 bits – color image – 16,7 million colors
  - JPEG
  - Mr. Sid

uncompressed

- RAW – RGB
- TARGA
- BMP

compressed

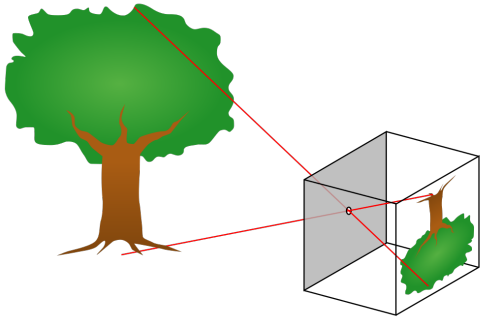
- lossless (ratio: 1:2-4)
  - PCX
  - GIF
  - PNG
- loss - making (ration 1:10-50)
  - JPEG
  - Mr. Sid

Pinhole Camera Model

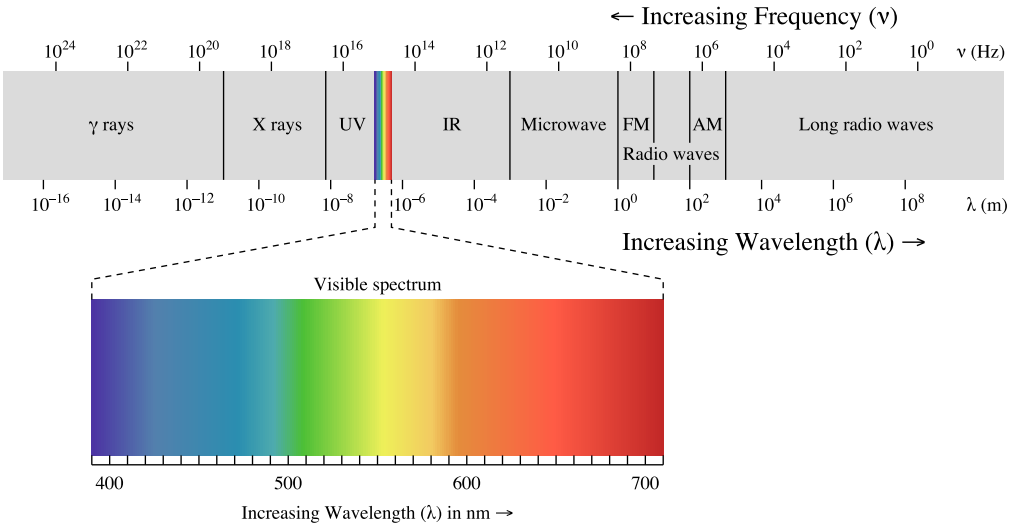
- perspective projection
- real 3D point $[x, y, z]^T$ is transformed to 2D image point $[u, v]^T$ as follows

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} f\frac{x}{z} \\ f\frac{y}{z}, \end{bmatrix} \qquad (3)$$

  where f is a focal length.
- Size of the hole influences the image sharpness.

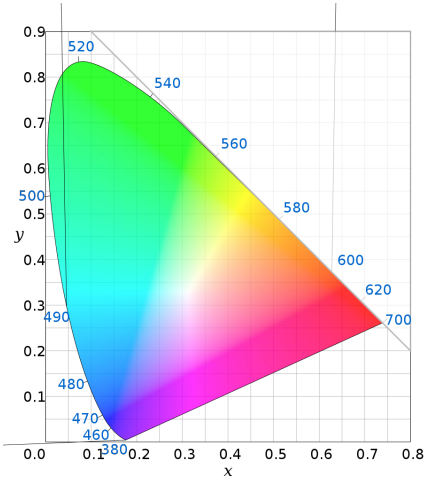


Electromagnetic spectrum



Color Standards – 1931 Commision Internationale de l'Eclairage (CIE)

- Spectral colors – left, top and right edge of the CIE diagram.
- Non-spectral colors – not included in sun spectrum – bottom edge of the CIE diagram.
- Maximum saturation on the edge. Minimum in the center.
- White light $x = y = \frac{1}{3}$



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Color mixing

Additive mixing

- Mixing of light sources
- Black color – all color components have zero value
- White color – all color components have maximum value

Subtractive mixing

- Subtracting from light on the object surface $\Rightarrow$ Color object
- Black color – all color components have maximum value
- White color – all color components have zero value

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Color representations

Artists

- Tint – mixture of a color with white light ⇒ reduces darkness ⇒ reduces saturation.
- Shade – mixture with black ⇒ increases darkness ⇒ reduces brightness
- Tone – produced either by mixing a color with grey, or by both tinting and shading

Computers

- Intensity – R+G+B channels
- Hue – average wave length
- Saturation – decrease of white color
- RGB model – Red, Green, Blue – additive mixing
- CMY(K) – Cyan, Magenta, Yellowm, (Black)– subtractive mixing

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Thank you for your attention!

Questions?