DRIVES

Development and Research on Innovative Vocational Education Skills

COMPUTER VISION FUNDAMENTALS

U2.E3. IMAGE FORMATION

Computer Vision Expert

May 2021, Version 1

Co-funded by the Erasmus+ Programme of the European Union

The Development and Research on Innovative Vocational Educational Skills project (DRIVES) is co-funded by the Erasmus+ Programme of the European Union under the agreement 591988-EPP-1-2017-1-CZ-EPPKA2-SSA-B. The European Commission support for the production of this publication does not constitute endorsement of the contents which reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

LEARNING OBJECTIVES

The student is able to …

CVE.U2.E3.PC1	Understands what an image is.
CVE.U2.E3.PC2	Know the different types of images.
CVE.U2.E3.PC3	Arrange an image as a matrix.
CVE.U2.E3.PC4	Define the process of image formation in the eye.
CVE.U2.E3.PC5	Understand the process of digital image formation.
CVE.U2.E3.PC6	Understand the steps behind image formation.
CVE.U2.E3.PC7	List, define and understand the factors in image formation: geometry, radiometry, photometry and digitization.
CVE.U2.E3.PC8	Recognize and comprehend the challenges behind image formation.

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Artifact that depicts visual perception

Physical likeness or representation of a person, animal, or thing, photographed, painted, sculptured, or otherwise made visible.

Representation of something or someone or a photograph or an idea you are picturing in your head or the way you or others think of you.

The visual impression of something, produced variously as by reflection from a mirror, refraction through a lens, electromagnetic or ultrasound scanning, etc.

TYPES OF IMAGES

Binary image: The binary image as it name states, contain only two pixel values. 0 and 1. In our previous tutorial of bits per pixel, we have explained this in detail about the representation of pixel values to their respective colors. Here 0 refers to black color and 1 refers to white color. It is also known as Monochrome.

Black and white image: The resulting image that is formed hence consist of only black and white color and thus can also be called as Black and White image. **No gray level**

Color IMAGE: 2, 3, 4,5, 6 bit: The images with a color format of 2, 3, 4, 5 and 6 bit are not widely used today. They were used in old times for old TV displays, or monitor displays. But, each of these colors have more then two gray levels, and hence has gray color unlike the binary image. In a 2 bit 4, in a 3 bit 8, in a 4 bit 16, in a 5 bit 32, in a 6 bit 64 different colors are present.

TYPES OF IMAGES

8 bit color format: 8 bit color format is one of the most famous image format. It has 256 different shades of colors in it. It is commonly known as Grayscale image. The range of the colors in 8 bit vary from 0-255. Where 0 stands for black, and 255 stands for white, and 127 stands for gray color.

16 bit color format: It is a color image format. It has 65,536 different colors in it. It is also known as High color format. It has been used by Microsoft in their systems that support more then 8 bit color format. Now in this 16 bit format and the next format we are going to discuss which is a 24 bit format are both color format. The distribution of color in a color image is not as simple as it was in grayscale image.

24 bit color format: 24 bit color format also known as true color format. Like 16 bit color format, in a 24 bit color format, the 24 bits are again distributed in three different formats of Red, Green and Blue.

Their distribution is like this. 8 bits for R, 8 bits for G, 8 bits for B.

IMAGE FILE FORMATS

JPEG (pronounced JAY-peg) is a graphic image file produced according to a standard from the Joint Photographic Experts Group, an ISO/IEC group of experts that develops and maintains standards for a suite of compression algorithms for computer image files.

GIF (pronounced JIF by many, including its designer; pronounced GIF with a hard G by many others) stands for Graphics Interchange Format.

GIF89a is an animated GIF image, formatted according to GIF Version 89a. One of the chief advantage format is the ability to create an animated image.

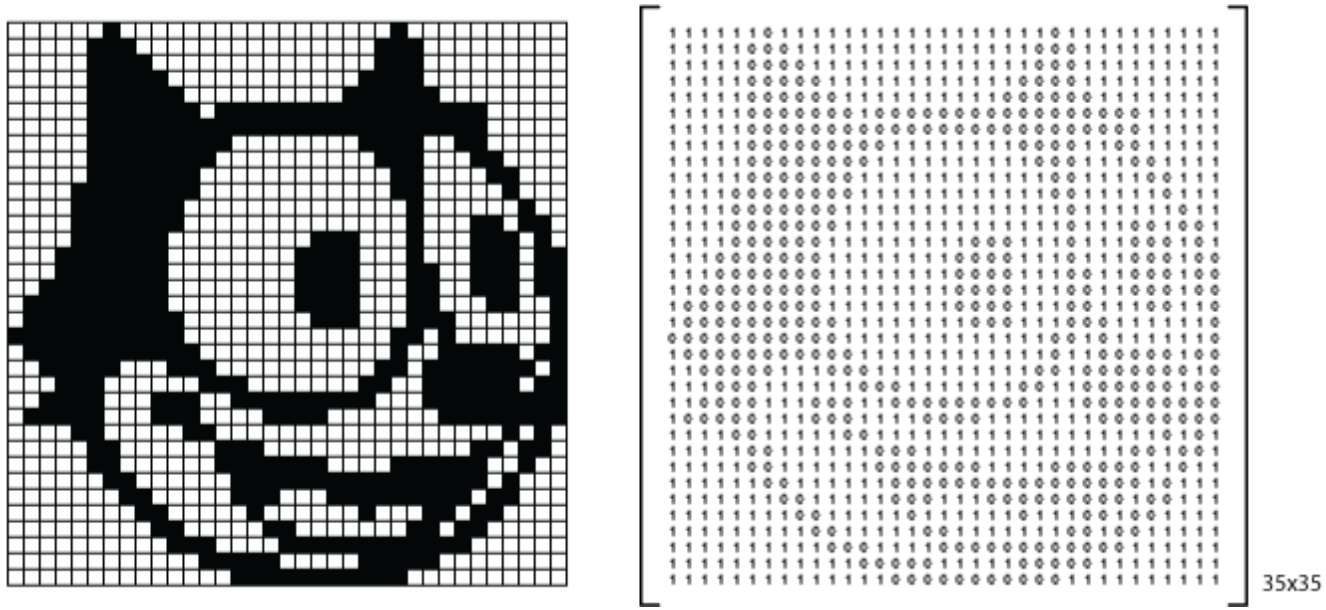
PNG (pronounced *ping*) is a Portable Network Graphics) is a file format for image compression that was designed to provide a number of improvements over the GIF format.

SVG is Scalable Vector Graphics, the description of an image as an application of XML.

TIFF (Tag Image File Format) is a common format for exchanging raster graphics (bitmap) images between application programs, including those used for scanner images.

IMAGE AS A MATRIX

An image is an array, or a matrix, of square pixels arranged in columns and rows.

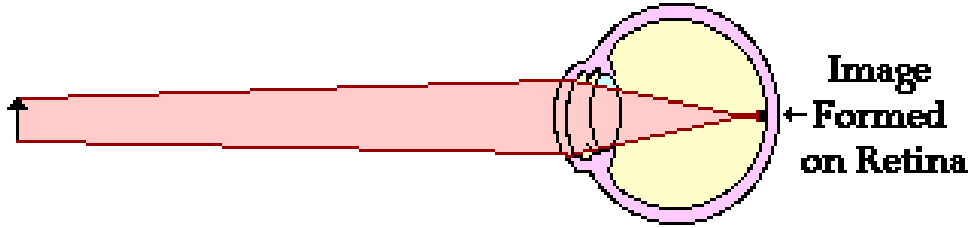


Each element of the matrix determines the intensity of the corresponding pixel. Most of the digital files use integer numbers between 0 (to indicate black) and 255 (to indicate white), giving a total of 256 different levels of gray.

OUR EYE: IMAGE FORMATION PROCESS

In the figure below, we can see the formation of image in the eye.

1. The object is typically located at a point in space more than 2-focal lengths from the "lens";
2. The image will be located somewhere between the focal point of the "lens" and the 2F point;
3. The image will be inverted, reduced in size, and real;
4. The cornea-lens system produces an image of an object on the retinal surface, this process is known as **accommodation**;
5. The reduction in the size of the image allows the entire image to "fit" on the retina.



The cornea and lens serve to refract light and focus an image of the object upon the retinal surface.

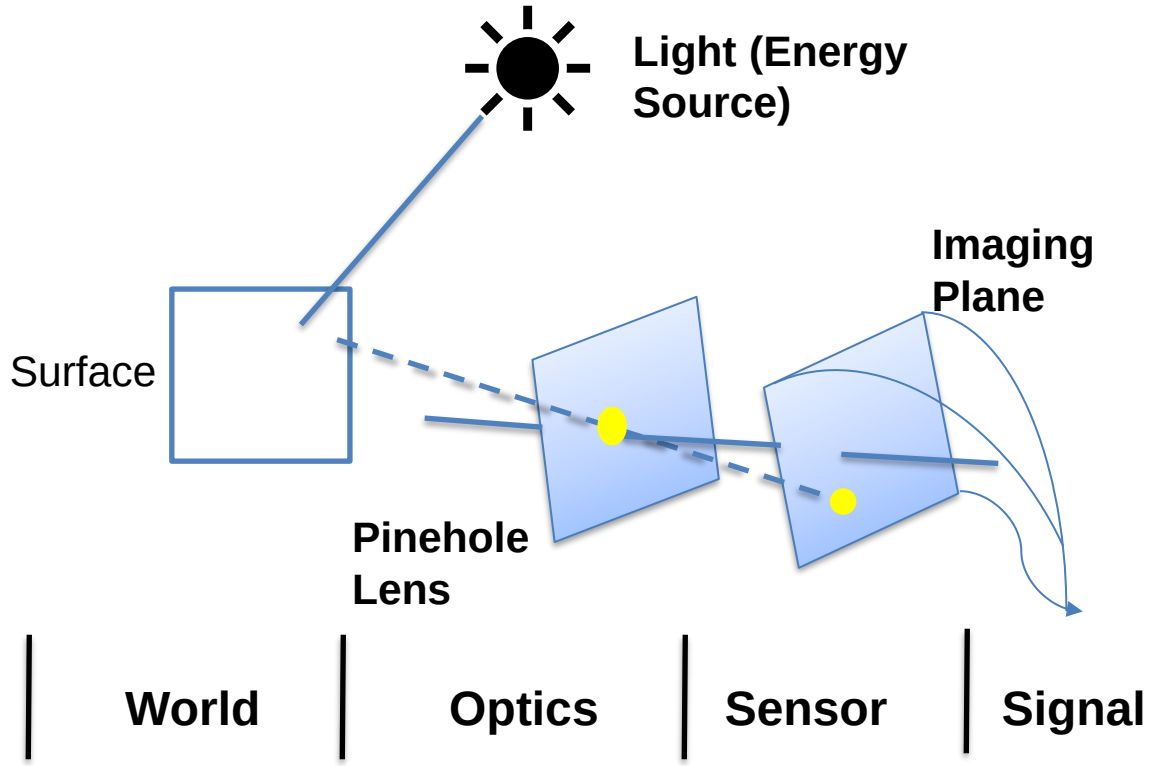
Several factors are responsible for the degradation of retinal images: diffraction of light in the pupil of the eye, optical aberrations (chromatic and monochromatic), and intraocular scattering.

PROCESS OF DIGITAL IMAGE FORMATION

Reality	Focus light from world on sensor	Converts light to electrical energy	Representation of incident light as continuous electrical energy	Digitizer converts continuous signal to discrete signal	Final representation of reality in computer memory

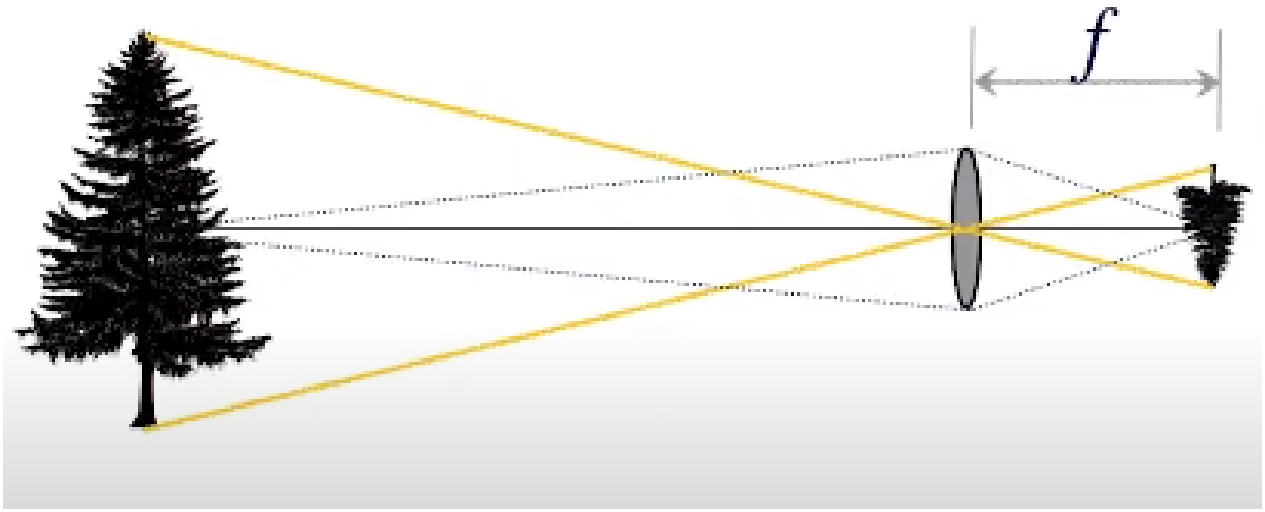
In a simple model, first the scene is illuminated by a single source, then the scene reflects radiation towards the camera and lastly, the camera senses it via chemicals on film.

PROCESS OF DIGITAL IMAGE FORMATION



PROCESS OF DIGITAL IMAGE FORMATION

f represents the distance away from the lens, between where we want to be able to capture the image, and where we put the sensor (at the focal plane of a lens) .



PROCESS OF DIGITAL IMAGE FORMATION

The digital image is the result of the convolution of the reception pattern (a) with the object (b). The image is further enhanced when the pixel illumination is normalized in accordance to the reception pattern.

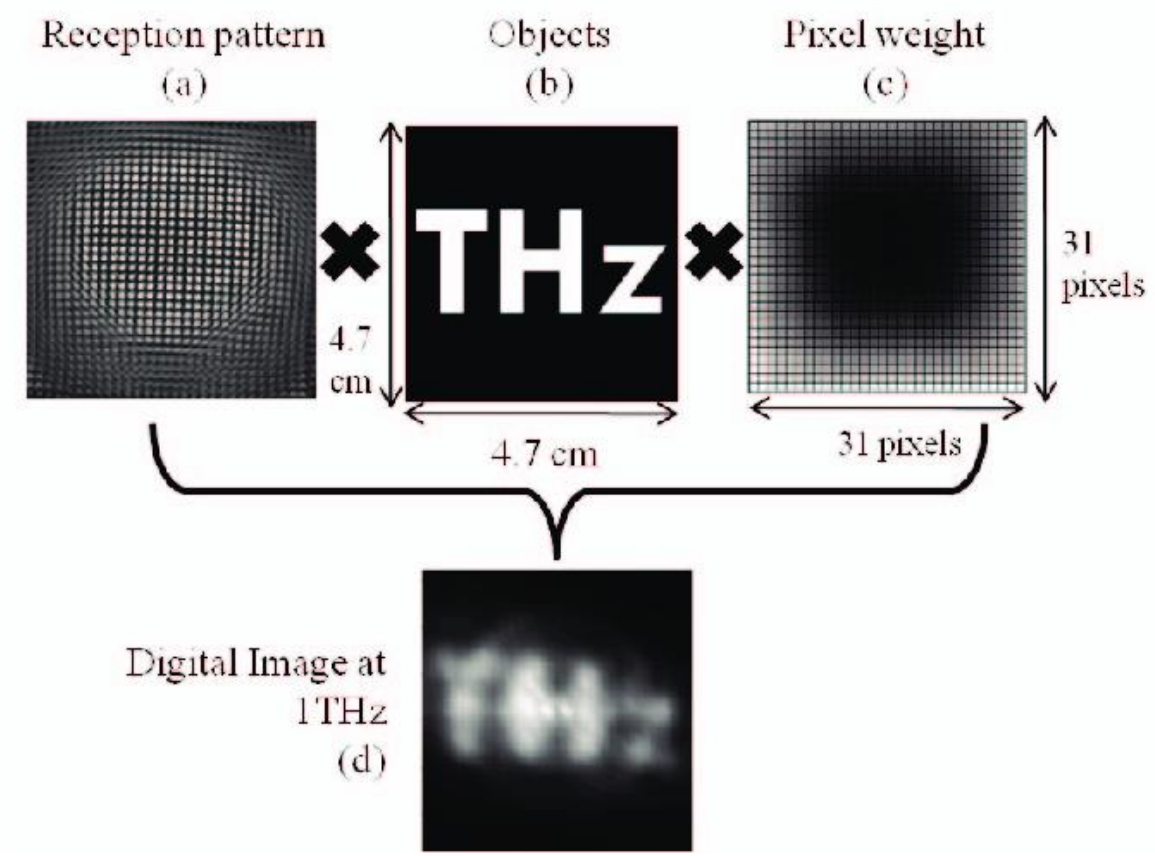


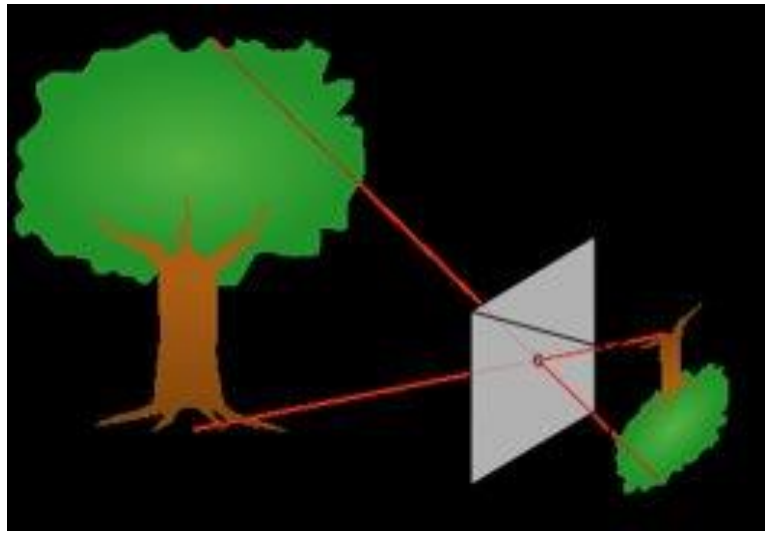
IMAGE FORMATION: **GEOMETRY**

Geometry describes the projection of:

three-dimensional (3D) world → two-dimensional (2D) image plane

Each point in the image corresponds to a particular direction defined by a ray from that point through the Pinhole (also called the central projection ray). Pin-hole is the basis for most graphics and vision. A pinhole serves as a useful focusing element because only the rays passing within a narrow angle are used to form the image.

Pinhole camera image



Kinds of projections:

- Perspective
- Oblique
- Orthographic
- Isometric
- Spherical

IMAGE FORMATION: **RADIOMETRY**

Radiometry is the part of image formation concerned with the relation among the amounts of light energy emitted from light sources, reflected from surfaces, and registered by sensors. It is concerned with the relationship between the amount of light radiating from a surface and the incident amount at its image.

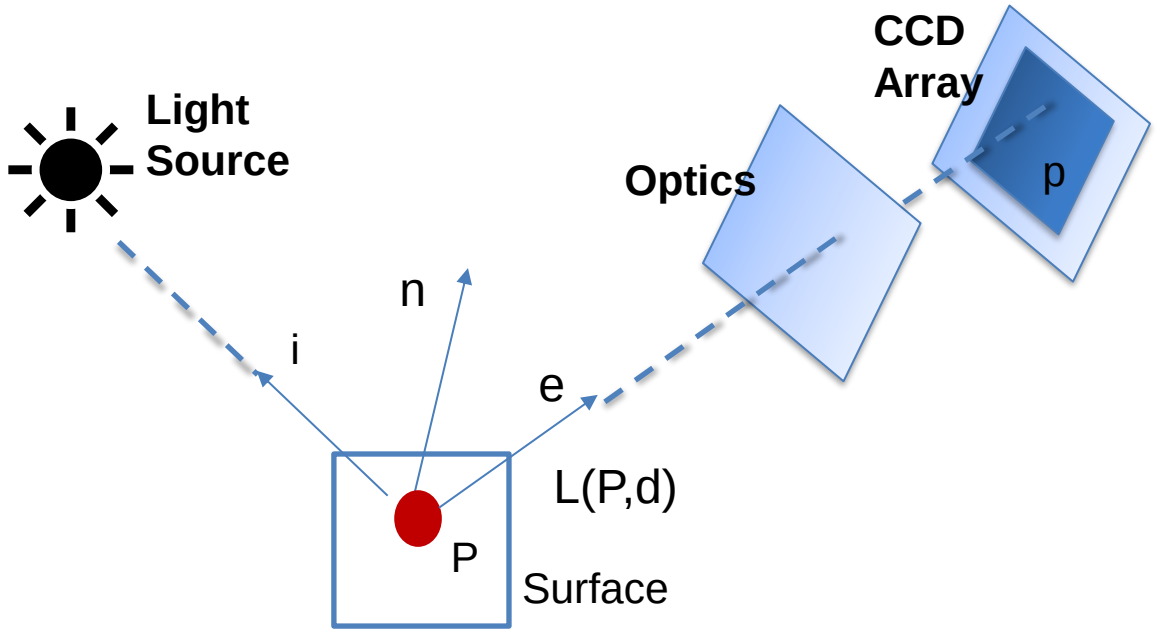


IMAGE FORMATION: **RADIOMETRY**

- Radiometry is a branch of physics studying the flow and the transmission of excited energy.

- Radiometry enables to explain image formation mechanism. Informally, the brightness in a pixel depends on the shape of the object, the reflectance properties of its surface, the position of the viewer, positions and types of illumination sources.

IMAGE FORMATION: **PHOTOMETRY**

Photometry uses analogical quantities as radiometry but takes into account human perception system properties.

Photometric quantities depend also on a spectral characteristics of the illumination source and the sensitivity of the photosensitive cells on the human eye retina. This concept is concerned with ways of measuring the intensity of light.

Photometric image formation

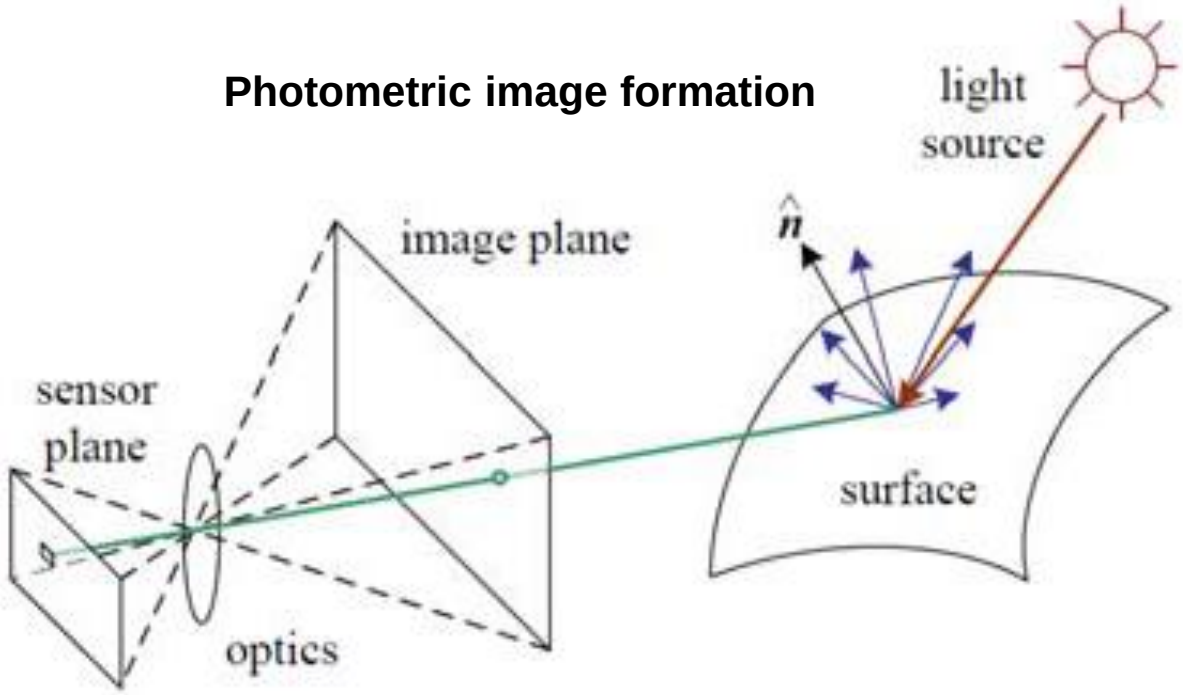


IMAGE FORMATION: **DIGITIZATION**

Digitization: conversion of the continuous (in space and value) electrical signal into a digital signal (digital image).

a

b

c

d

a) Original image at 256 gray scale levels; b) 64levels; c) 8levels; d) 2levels.

IMAGE FORMATION: **DIGITIZATION**

A digital image can be represented as a matrix **i** having dimensions $N \times M$ elements (pixels):

$$\mathbf{i} = \begin{bmatrix} i(1,1) & \cdots & i(1,M) \\ \vdots & \ddots & \vdots \\ i(N,1) & \cdots & i(N,M) \end{bmatrix},$$

Or as a vector of NM elements $\mathbf{i} = [i(1,1),\ldots,i(1,M),\ldots i(N,M)]^T$.

Three decisions must be made:

- Spatial resolution (how many samples to take);
- Signal resolution (dynamic range of values);
- Tessellation pattern (how to 'cover' the image with sample points).

IMAGE FORMATION: **CHALLENGES**

Image formation geometry has some consequences such as:

- Variability in appeareance - deals with variability of rigid, planar shapes under perspective distortion, or piecewise rigid, planar shapes.

In Photometry there are some factors influencing performance:

- Optical distortion: pincushion, barrel, non-linearities;
- Sensor dynamic range (30:1 CCD, 200:1 vidicon);
- Sensor Shading (nonuniform responses from different locations)

.

IMAGE FORMATION: **CHALLENGES**

As the imaging hardware captures more and more amounts of data, efficient computational technologies are needed because the algorithms become more complex. This is a big challenge addressed by more powerful graphical processors and multiprocessing techniques that allow a completely new scale of opportunities for transitioning from research to applications.

SUMMARY

- In a simple process of image formation first the scene is illuminated by a single source, then the scene reflects radiation towards the camera and lastly, the camera senses it via chemicals on film.
- Geometry is concerned with the relationship between points in the three-dimensional world and their images.
- Radiometry enables to explain image formation mechanism.
- Photometry is concerned with ways of measuring the intensity of light.
- Digitization is the conversion of the continuous electrical signal into a digital signal.
- The algorithms became more complex, so new efficient computational technologies are needed.

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This Training Material has been certified according to the rules of **ECQA – European Certification and Qualification Association.**

The Training Material was developed within the international job role committee **“Computer Vision Expert”:**

UMINHO – University of Minho (https://www.uminho.pt/PT)

The development of the training material was partly funded by the EU under Blueprint Project DRIVES.

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Thank you for your attention

DRIVES project is project under **The Blueprint for Sectoral Cooperation on Skills in Automotive Sector**, as part of New Skills Agenda.

The aim of the Blueprint is **to support an overall sectoral strategy and to develop concrete actions to address short and medium term skills needs.**

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