

# RoboCup 2010



## 1. Color and Luminance

## Digital Image

### Definition:

- **Digital image / raster image / bitmap image:**
  - Finite set of digital values (pixels)
  - Fixed number of rows and columns of pixels (defines width and height of the image)
  - Stored as a two-dimensional array of integer values
  - Fixed range of pixel values:
    - Binary: {0, 1}
    - Greyscale: {0..255}
    - Color (RGB) : {0..255} for each color channel
  - Video from camera: sequence of images (frames)
  - File formats to store images: JPEG, BMP, GIF, PNG

## Definition of Colors (I)

### Definitions:

- **Color:** Sense perception (no physical feature) when light of a certain wavelength falls on the retina of the eye. The sensory cells in the human eye (cones for colors, rods for brightness value) release impulses to the brain, which perceives these as colors. Human possesses three types of cones (sensitive for red, green, and blue).
- **Visible light:** between 400 – 700 nm



Source: Wikipedia.de

- **Color space:** group of colors to be available
- **Color model:** Describes the color space an input or output device (display, scanner, printer, projector, photo, camera, television) is able to illustrate.

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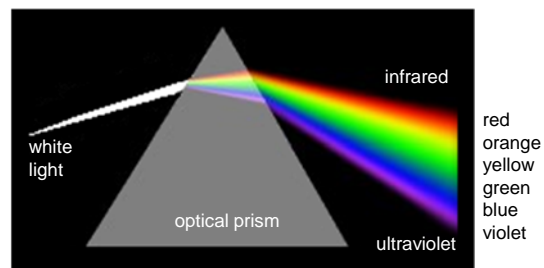
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## Definition of Colors (II)

### Basis of colors:

- discovery 1666 by Newton: sunlight which falls through a prism is split up into a continuous range of colors.



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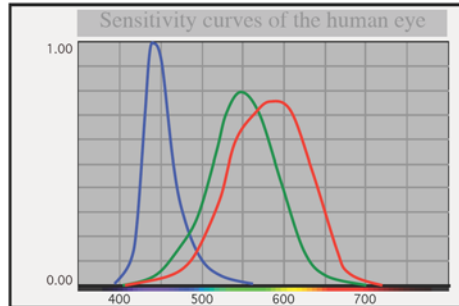
# Human Perception (I)

The retina of the human eye does consist of:

- Cones (cone cells): Identification of colors
- Rods (rod cells): Identification of brightness values

Cones contain three types of pigments which are sensitive to specific colors:

- Low frequencies: blue colorings
- Median frequencies: green/yellow colorings
- High frequencies: red colorings

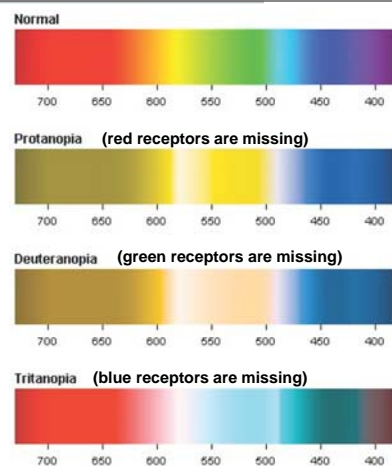


source: Gabriel Marcu, Apple

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# Human Perception (II)

- In case that one of the pigments transfers no complete signals, one speaks of color blindness.
- 10 % of the population can perceive colors only restrictively

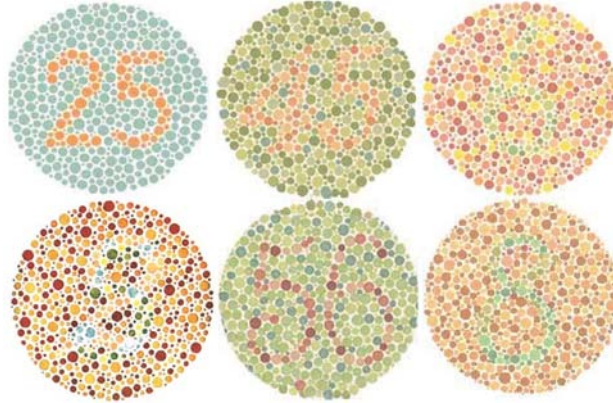


source: Gabriel Marcu, Apple

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## Human Perception (III)

Ishihara test for the detection of color blindness



source: Gabriel Marcu, Apple

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## Color space (I)

### Composition of a color space:

- **Coordinate system** in which single colors define the axes (due to the human eye's construction mostly 3 dimensions).
- Physical color models (mixture of colors): RGB, CMYK (printer)
  - arrangement as dice
  - modification of a color → simultaneous modification of brightness, chroma, and coloring
  - In 1931, definition of the elementary colors by the CIE (International Commission on Illumination): red (=435,8 nm), green (=546,1 nm), and blue (=700 nm)
- Perception oriented color models (description by brightness, chroma, and coloring): HSV, HSI
  - description by cylindrical coordinates (angle defines the color)

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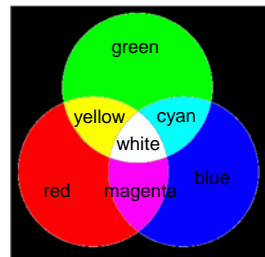
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## Color space (II)

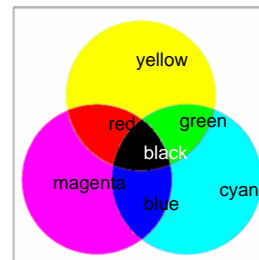
### Additive color space

- Elementary colors add up to white
- Displays / projectors use the elementary colors RGB



### Subtractive color space

- Elementary colors are subtracted from white
- Ink jet printer (pixels absorb white light),
- Slides in front of a white lamp filter single color components



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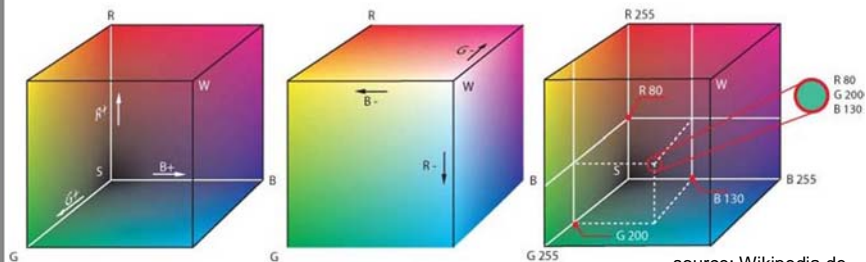
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## Color space (III)

### Physical color model: RGB color space

- idea: out of the colored light of three elementary colors one can mix arbitrary colors
- additive color space (colors add up to white)
- 8 bit / 16 bit per color channel



source: Wikipedia.de

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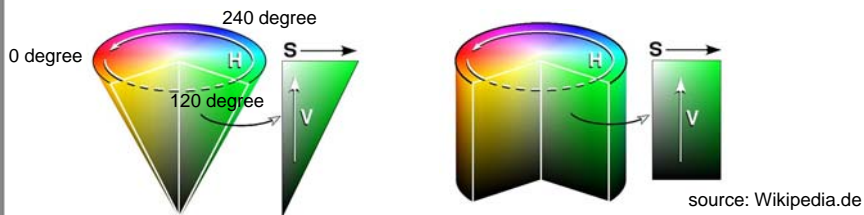
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# Color space (IV)

## Perception-oriented color model: HSV color space

- Hue (color): dominant wavelength (dominant color by which a human describes an object)
- Saturation (chroma): describes how strong a color is, i.e. the mixture ratio of one color with another color (ratio of dominant wavelength to other wavelengths).
- Value (intensity): brightness of a color



source: Wikipedia.de

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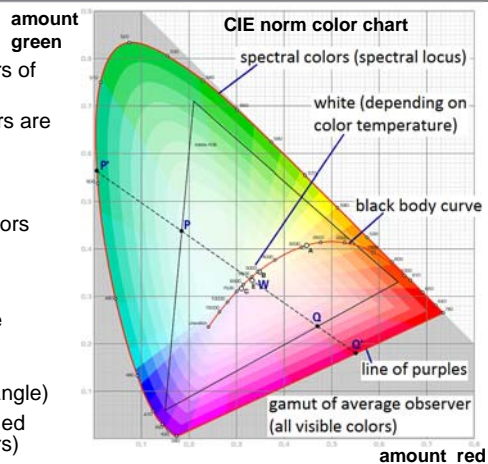
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# Color space (V)

## RGB color space

- parabolically limited (visible colors of an average human observer)
- pure (completely saturated) colors are on the spectral color line
- mixed color: in the interior of the diagram
- white: combination of several colors with similar intensities
- combination of two colors: all combinations on a straight line between these two colors can be created
- three colors span the RGB color space of the computer (black triangle)
- corners of the triangle are specified by different devices (e.g. monitors)



$$\text{amount red} + \text{amount green} + \text{amount blue} = 1$$

$$\rightarrow \text{amount blue} = 1 - \text{amount red} - \text{amount green}$$

source: Wikipedia.de

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# Color displays (I)

## Comparison of CRT and TFT displays

identical colors



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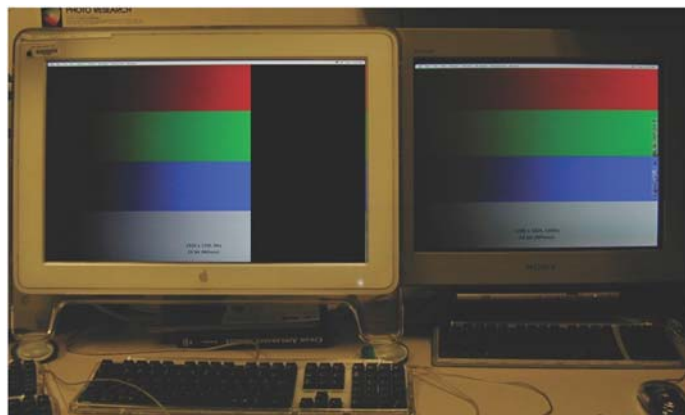
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# Color displays (II)

## Comparison of CRT and TFT displays (same color ranges)



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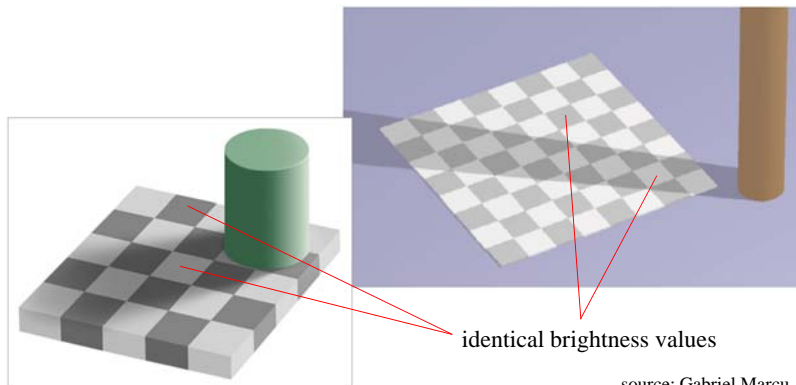
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# Human Perception (V)

Luminance is affected by forms, objects, and their shades



source: Gabriel Marcu, Apple

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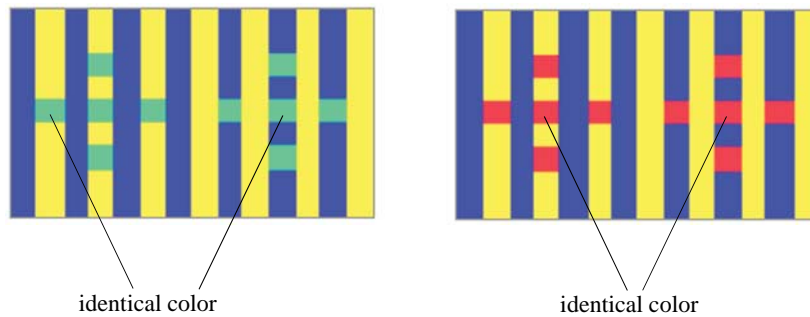
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# Human Perception (VI)

Colors are affected by neighboring color regions



source: Gabriel Marcu, Apple

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# Challenges

## Object recognition based on colors:

- Luminance and luminance changes
- Viewing direction of camera (lens aperture)
- Automatic camera adjustment (white ballance)
- Reflections
- Many colors describe one object
- Shadows
- Blurring
- ...