Computer Vision

Color image processing

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Color image processing

Overview:

- **Introduction**
- **Color spaces**
- **Extract and merge channels**
- **Image enhancement**
- **Segmentation**
- **False color images**
- **Exercise**

Introduction

- **Electromagnetic spectrum**
- **Human vision**
- **Color systems**
- **Sensing illuminated objects**

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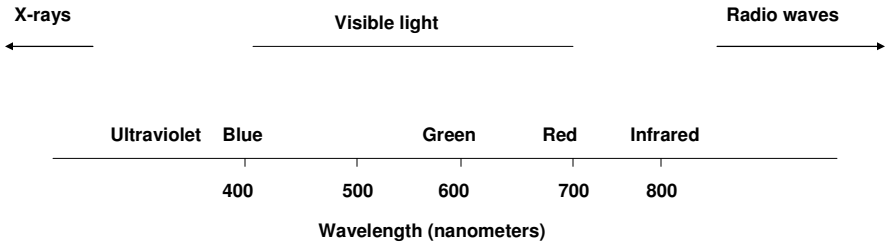
Electromagnetic spectrum



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Human vision

Human eye:

- **Bars for gray values**
- **Cones for color, one type for each primary color**
  - **Blue**
  - **Green (most sensitive)**
  - **Red**

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Color systems

- **Additive:**
  the primary colors of light are individual red, green and blue light sources that are projected onto a common region of space to reproduce a colored light.

  Example: RGB monitor.

- **Subtractive:**
  the primary pigments are magenta, cyan and yellow. A primary pigment subtracts or absorbs a primary color of light and reflects or transmits the other two primaries of light.

  Example: white light on yellow object: blue is absorbed <subtractive>, red and green (= yellow) are reflected <additive>.

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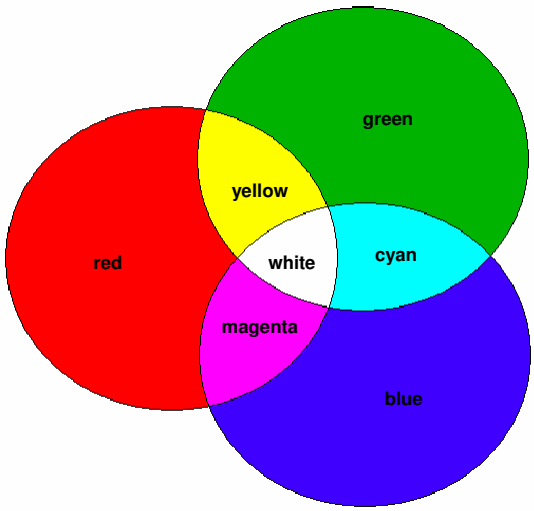
Mixtures of light (additive primaries)



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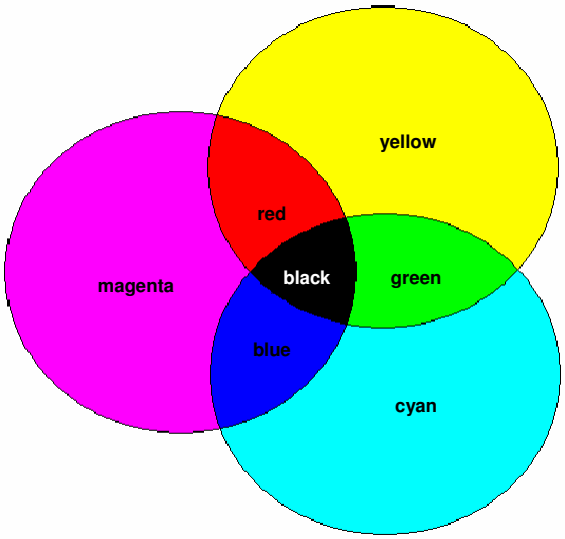
Mixtures of pigments (subtractive primaries)



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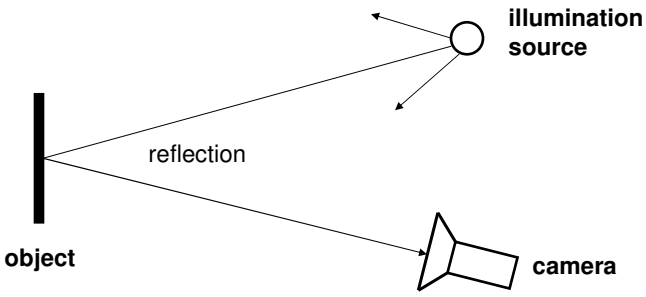
Sensing illuminated objects



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Sensing illuminated objects

The sensation, or perception, of an object's color depends upon three factors:

- **The spectrum of energy in the various wavelengths illuminating the object surface**
- **The spectral reflectance of the object surface, which determines how the surface changes the received spectrum into the radiated spectrum**
- **The spectral sensitivity of the sensor irradiated by the light from the object's surface**

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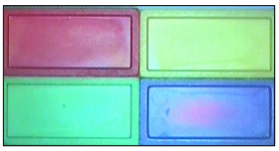
Sensing illuminated objects

White light contains all colors in equal energy

Domino stones illuminated by equal amounts of red, green and blue



Note: both domino stones and light source do not have pure colors

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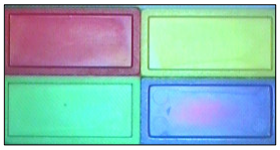
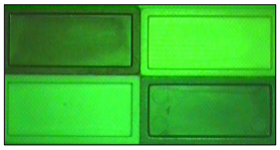
Sensing illuminated objects

white light



green light



- **green -> green**
- **yellow -> light green (yellow = green + red)**
- **blue -> dark**
- **red -> dark**

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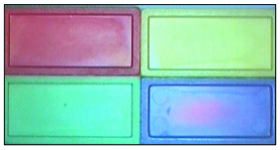
Sensing illuminated objects

white light **red light**



- **red -> red**
- **yellow -> red (yellow = green + red)**
- **blue -> dark**
- **green-> dark**

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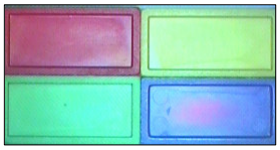
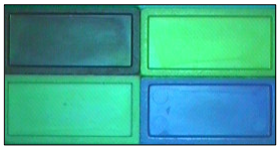
Sensing illuminated objects

white light **green/blue (cyan) light**





- **green -> green**
- **blue -> blue**
- **yellow-> green**
- **red -> dark**

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Color spaces

- **RGB**
- **HSV**
- **YUV**
- **Not treated:**
  - **nRGB (rgb)**
  - **HSI**
  - **HSL**
  - **YIQ**
  - **CMY(K)**
  - **CIELAB**
  - **CIELUV**

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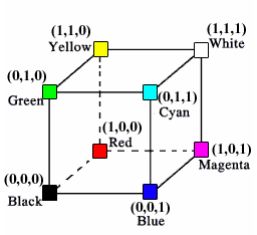
RGB space



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RGB space

RGB

- **Is used for displaying in CRT and LCD screens**
- **Non-intuitively,**
  "where is yellow in the cube?"
- **Non-uniform,**
  "which 3D shape should threshold values have ?"

VisionLab implementation RGB888Image and RGB161616Image:

- **8 or 16 bits for each color**
- **Result of 8 bit operations are clipped**

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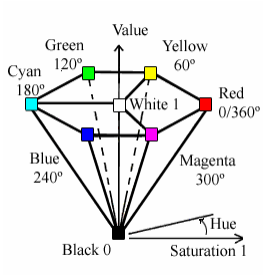
HSV space



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HSV space

HSV:

- **Hue: dominant color**
- **Saturation: relative purity (or the amount of white light mixed with the hue)**
- **Value: the amount of light (maximum of red, green and blue)**

Note:

- **Saturation is not defined when intensity = 0**
- **Hue is not defined when saturation = 0**

Other related spaces:

- **HSI and HSL**

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HSV space

HSV versus RGB

- **More intuitively**
- **More uniform**
- **Extra conversions**

VisionLab implementation HSV888Image and HSV161616Image:

- **8 or 16 bits for each component**
- **Hue: 0°.. 359° is mapped on 0 .. 255 for 8 bits and mapped to 0 .. 31416 for 16 bits**
- **Operations on Saturation and Value are clipped for 8 bits**
- **Operations on Hue are modulo 256 for 8 bits and modulo 31416 for 16 bits**

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YUV space

YUV:

- **Y: 0.30 * red + 0.59 * green + 0.11 * blue**
- **U: 0.493 * (blue – Y)**
- **V: 0.877 * (red – Y)**

Used as basis for PAL TV signals and in JPEG and MPEG compression

VisionLab implementation YUV888Image and YUV161616Image

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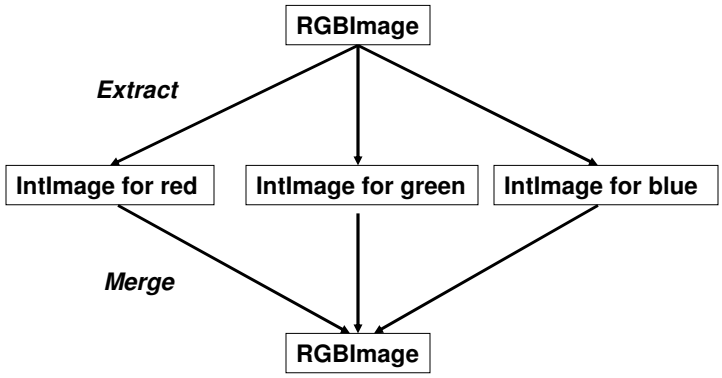
Extract and merge channels



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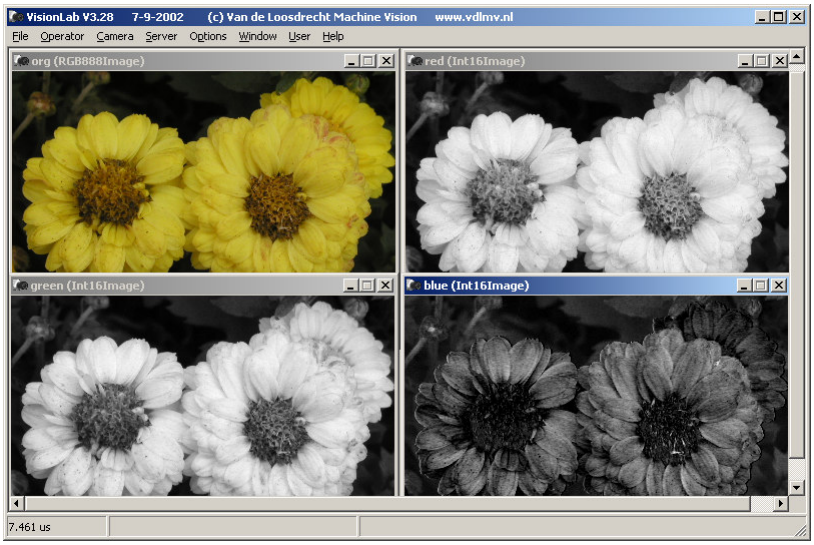
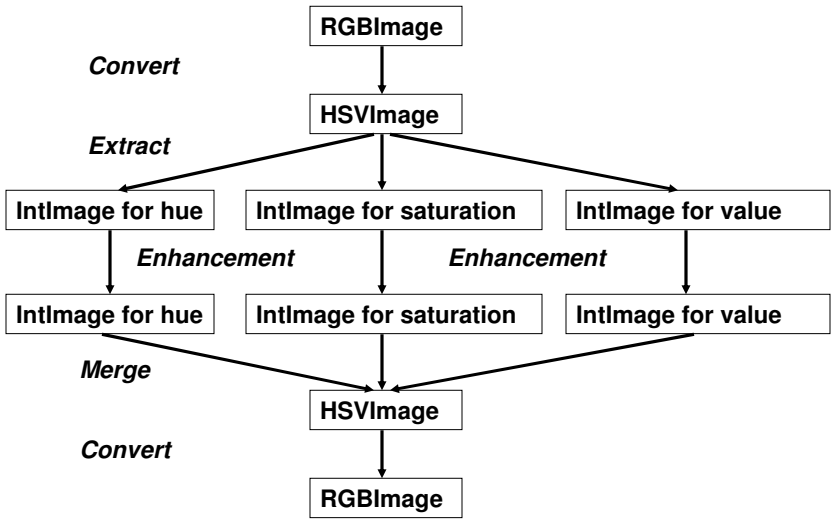
Example split RGB channels

- Open image dark_flower.jl
- Split in red, green and blue channel, useExtractRGBChannels from Color menu
- Merge the three channels using 3rd and 2nd select with MergeRGBChannels

Example split RGB channels



Typical schema for enhancement using grayscale operations



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Example contrast enhancement HSV

- Use script contrast_hsv.jls
  - Open image dark_flower.jl
  - Convert from RGB to HSV
  - Split in hue, saturation and value channel, use ExtractHSVchannels from Color menu
  - Histogram Equalize and Contrast Stretch value channel
  - Merge the three channels

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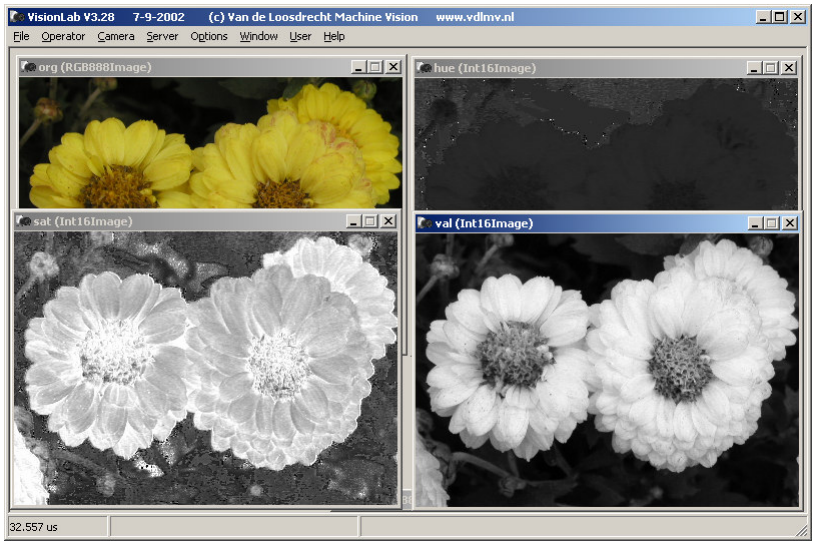
Convert and split HSV channels



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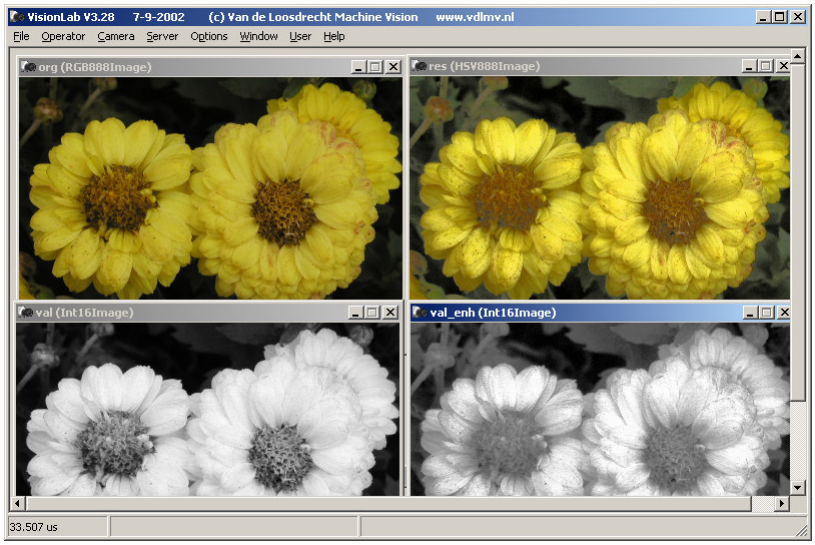
Enhance value channel and merge



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Exercise enhancement

Shoot color images or use image dark_flower.jl and experiment with :

- **Gray scale (contrast enhancement)**
- **Modify color by changing hue and/or saturation**

Segmentation

Segmentation on three channels
Most intuitively using HSV space

Tools in VisionLab

- **ThresholdHSVChannels**
- **ThresholdRGBChannels**
- **ThresholdTool**

Note for HSV thresholding:

- **Saturation is not defined when intensity = 0**
- **Hue is not defined when saturation = 0**

Example ThresholdHSVChannels

- **Open image domino.jl**
- **Convert to HSV888Image**
- **ThresholdHSVChannels 140 210 70 255 70 255**

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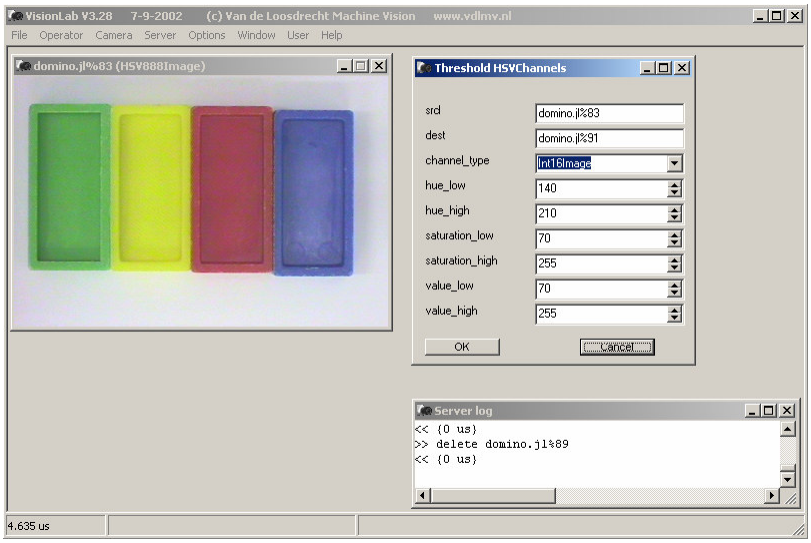
Example ThresholdHSVChannels



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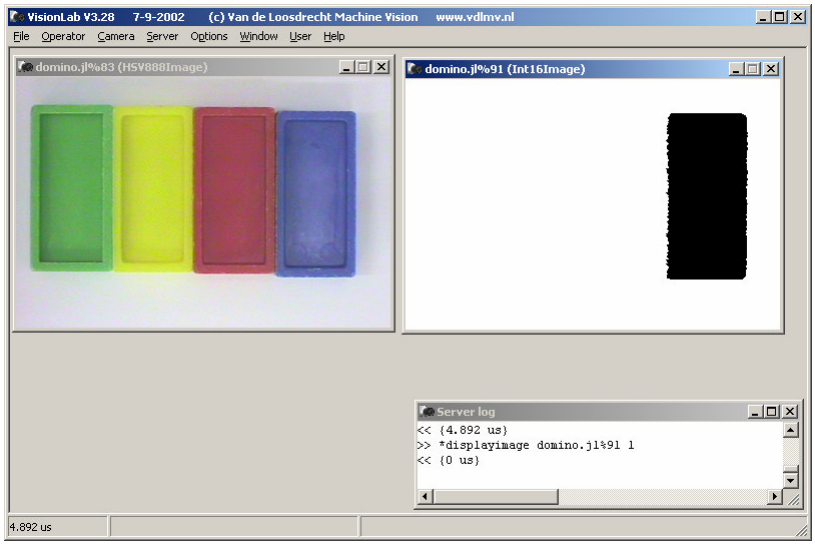
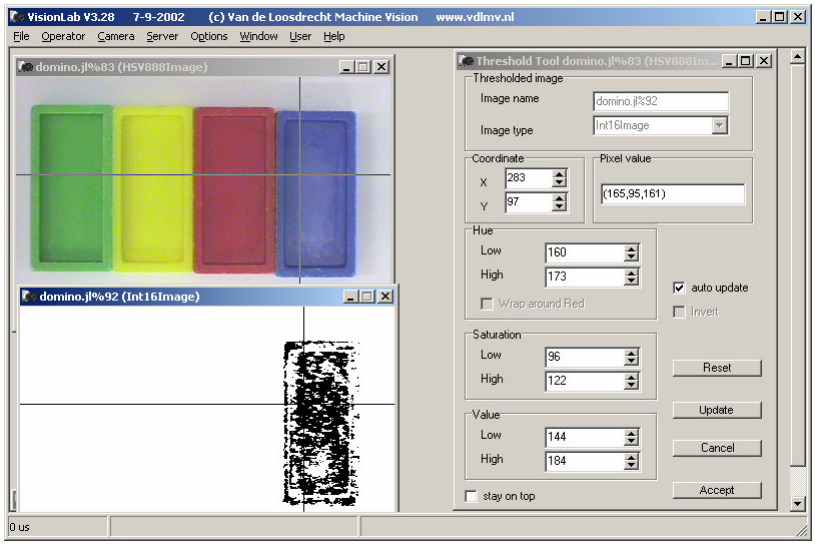
Example ThresholdHSVChannels



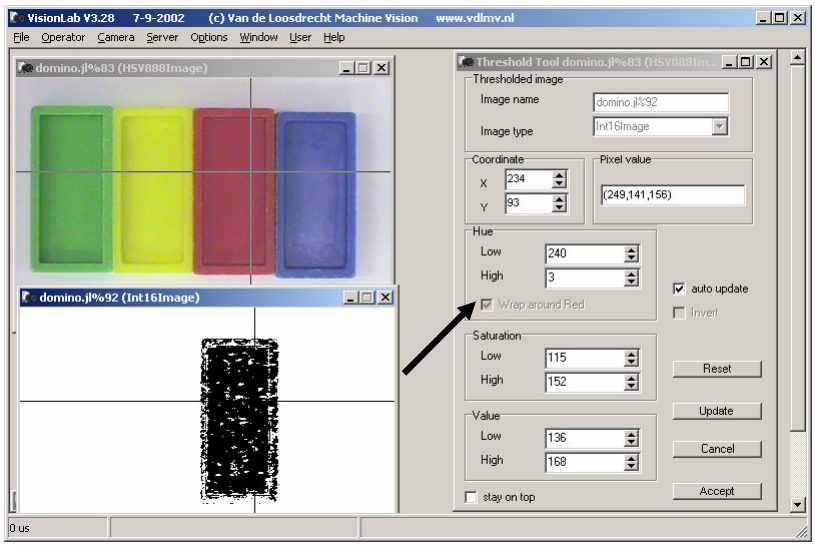
Example using ThresholdTool

- **Open image domino.jl**
- **Convert to HSV888Image**
- **Select ThresholdTool**
  - ***Note: "wrap around red should be off"***
  - **Select with mouse click all blue pixels**
  - **Click on accept**
  - **Do the same for the red domino stone, but then it goes wrong, ask why ?**
    - **For selecting red domino stone, set checkbox for "wrap around red" after "reset" parameters**

Example using ThresholdTool for blue stone



Example using ThresholdTool for red stone



False color image

ConvertToFalseColor (srcImage, LUTImage, destImage

This operator converts an OrdImage to an image with false colors. For this conversion an image is used as a LookUpTable. First the OrdImage in ContrastStreched and then the LUT is applied. The first pixel in de LUTImage has index 0.

Usage:

- **for displaying images with more contrast then possible with grayscale values**
- **for displaying measurement of temperatures**

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Example using ConvertToFalseColor

- **Open image hand.jl (infra red image)**
- **Open script gen_lut_rgb.jls**
- **Execute script to generate LUT**
- **ConvertToFalseColor hand lut (from Color menu)**
- **Open script gen_lut_hsv.jls**
- **Execute script to generate LUT**
- **ConvertToFalseColor hand lut**
- **Open script gen_lut_hsv2.jls**
- **Execute script to generate LUT**
- **ConvertToFalseColor hand lut**

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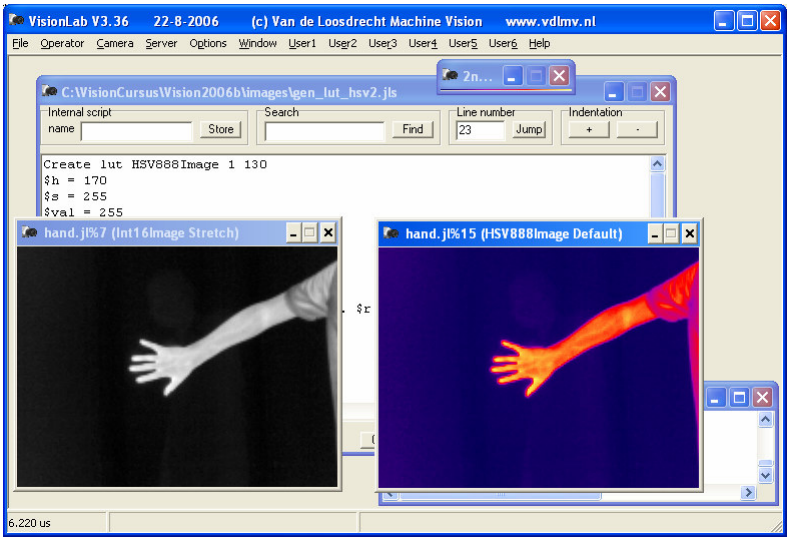
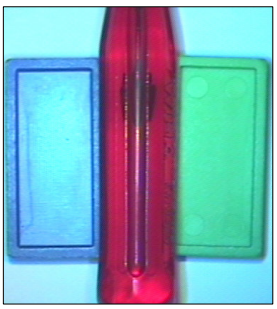
Using LUT hsv2



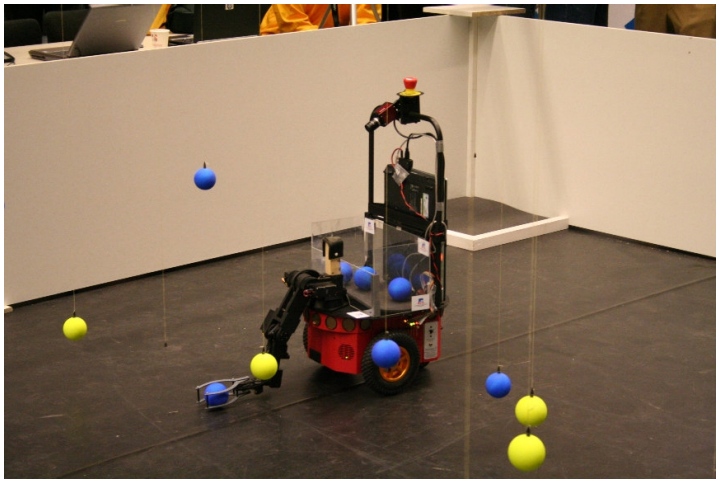
Exercise change red to blue (*)

Change the color of the screwdriver (image screwdriver.jl) from red to blue without changing the colors of the domino stones

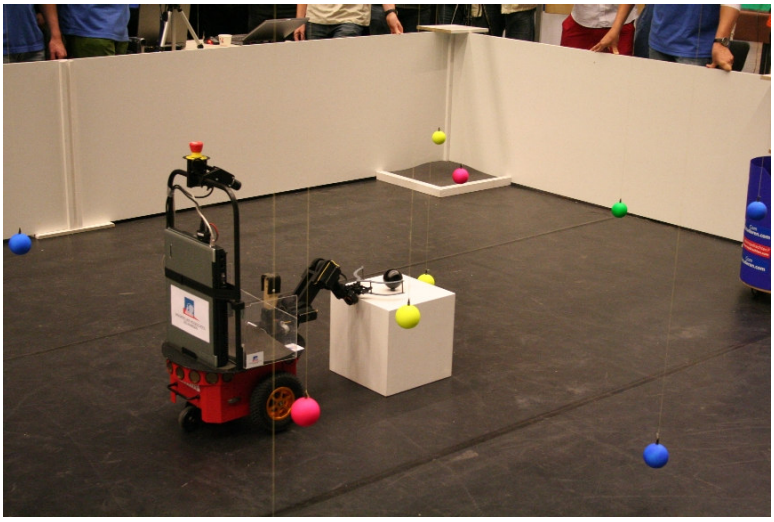


Answer: red_to_blue.jls

Robo Challenge

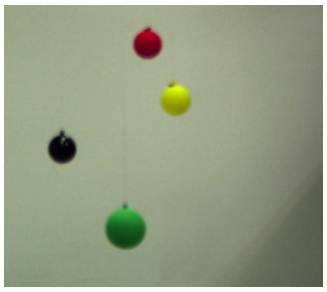


Robo Challenge



Exercise find balls

- **Use image robot_balls.jl**
- **Try to find the balls in:**
  - **Grayscale**
  - **RGB**
  - **YUV**
  - **HSV**



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Find balls in grayscale

- **Open robot_balls.jl**
- **Convert to Int16Image**
- **Use ThresholdTool, select bottom of black ball, set low to 0 and increment high to 140**
- **Conclusion:**
  - **Finding yellow and green ball is difficult**

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Find balls in RGB color space

- **Open robot_balls.jl**
- **Select yellow ball with ThresholdTool**
- **Select red ball with ThresholdTool**
- **Select bottom of black ball,**
  still problem with reflection
- **Select green ball,**
  if top part with wire is selected, the black ball is selected
- **Conclusion:**
  - **better then grayscale**
  - **very sensitive for lighting variations and shadows**
  - **change in light condition is change in R G and B**
  - **lows and highs for selection are very critical**

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Find balls in HSV color space

- **Open robot_balls.jl**
- **Convert to HSV888Image**
- **Select yellow ball**
  H: 40-50, S: 150-255, V:80-255 (even 0-255 works, just thicker
- **Select red ball, (no wrap around red needed!)**
  H:235-255, S:10-255, V:30-255
- **Select black ball, start at bottom side,**
  (still problem with refection)
  H:0-255, S:0-255, V:0-52
- **Select green ball, start at bottom**
  H:80-100, S:140-255, V:0-255
- **(Filter on Formfactor en Eccentrity using LabelBlobs and BlobAnalyse)**
- **Conclusion:**
  - **much more robust then RGB**

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