Content

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- Image file types
- Key terms for images
  - Pixels, pixel depth
- Main image formats
- Image files
  - Raster Formats: PNM, BMP, GIF, PNG, JPEG
  - Vector Formats: SVG

- (Video files)

Raster Format

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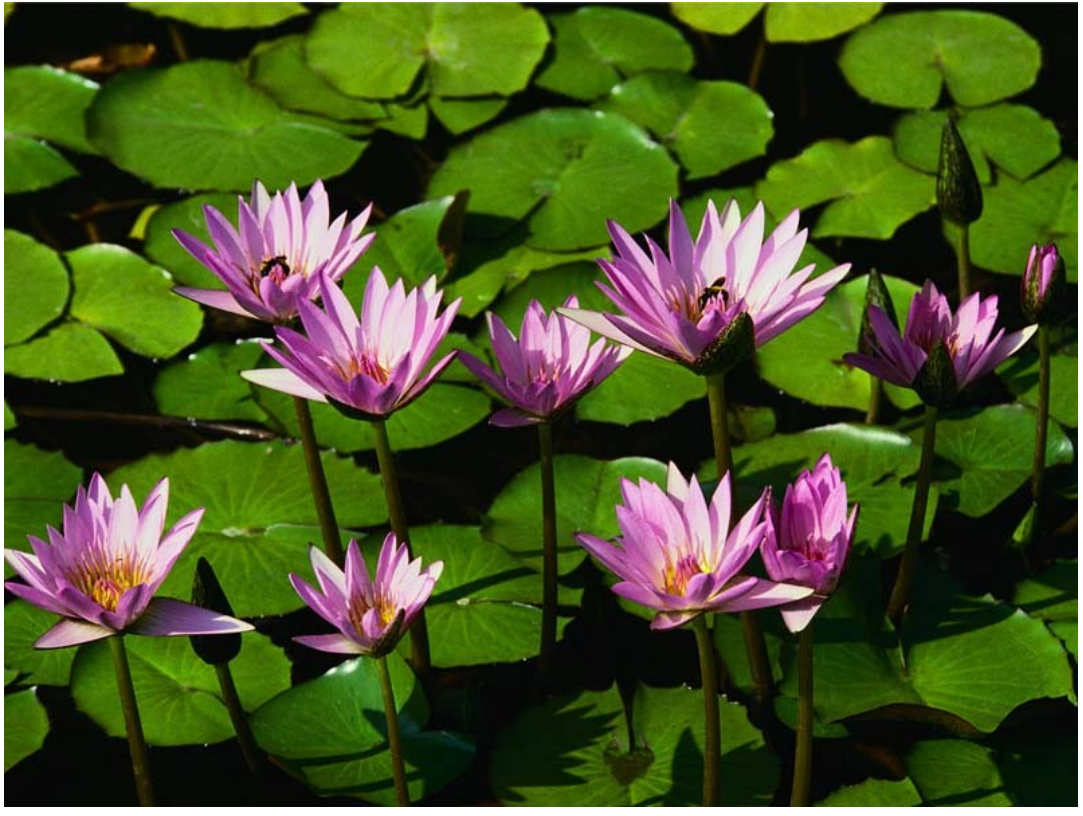

Raster Format

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Raster Format

Raster Format

Raster format

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- Also known as Bitmap format
  - Dot matrix data, namely a rectangular grid of **pixels**
  - Each pixel encodes “dot” information
  - Fixed resolution
    - Density ⟶ DPI
  - Widely used for digital cameras, scanners, printing…
  - A lot of different file formats

Pixels

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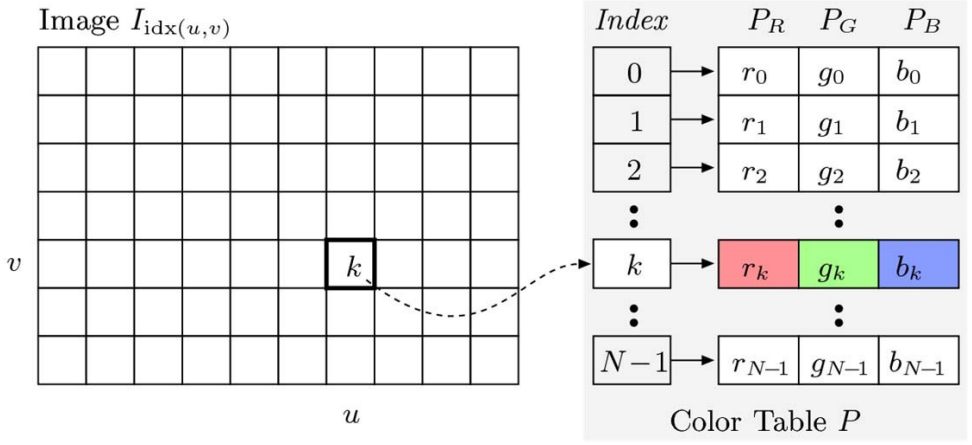
- Smallest *addressable* image element
  - Can be seen as a sample of the original image
- A pixel can contain different information
  - For greyscale images: luminance
    - Each pixel encodes “grey level”
    - Number of levels depends on **pixel depth**
      - Often 256 levels (0⟶black, 255⟶white), namely 8 bits
      - 2 levels for printing (monochrome, only 1 bit for pixel!)
  - Color
    - Again different levels ⟶ different number of colors
    - Also different formats

Indexed Colors

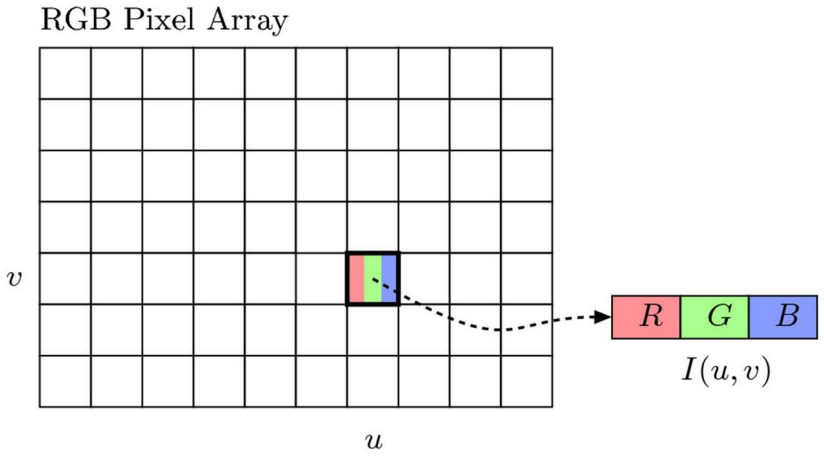
- Paletted images
  - Indexed colors
  - Also known as *color lookup table*



Credits: Emmanuel Agu

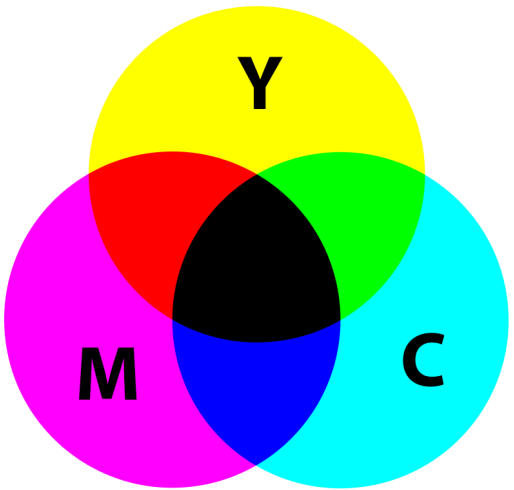
RGB family

- RGB
  - Each pixel encodes Red, Green, Blue channels
  - Different depths (24 bit considered as “true color”)
  - OpenCV uses BGR as default
- RGBA
  - Alpha channel used as % for transparency



CMYK

- Cyan, Magenta, Yellow and black (Key)
- Subractive color model
  - Cyan + Magenta + Yellow = black
- Main usage: printed materials

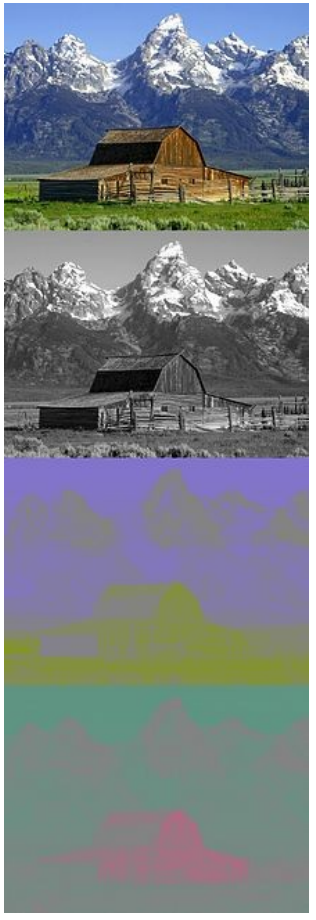


YUV

- Y'UV and Y'C_bC_r
  - Trying to mymic human vision
    - Cones & Rods cells
    - Luminance has a bigger importance than **Chrominance**
    - Do not encode colors but colors difference…
    - Widely used for image/video compression

$$\begin{pmatrix} Y \\ U \\ V \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{pmatrix} \cdot \begin{pmatrix} R \\ G \\ B \end{pmatrix} \qquad \begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1.000 & 0.000 & 1.140 \\ 1.000 & -0.395 & -0.581 \\ 1.000 & 2.032 & 0.000 \end{pmatrix} \cdot \begin{pmatrix} Y \\ U \\ V \end{pmatrix}$$

Y = 0.299R + 0.587G + 0.114B, U = 0.492(B-Y), V = 0.877(R-Y)



- Standardized variant of YUV
- Used for digital videos and some image format

$$Y = w_R \cdot R + (1 - w_B - w_R) \cdot G + w_B \cdot B$$

$$C_b = \frac{0.5}{1 - w_B} \cdot (B - Y)$$

$$C_r = \frac{0.5}{1 - w_R} \cdot (R - Y)$$

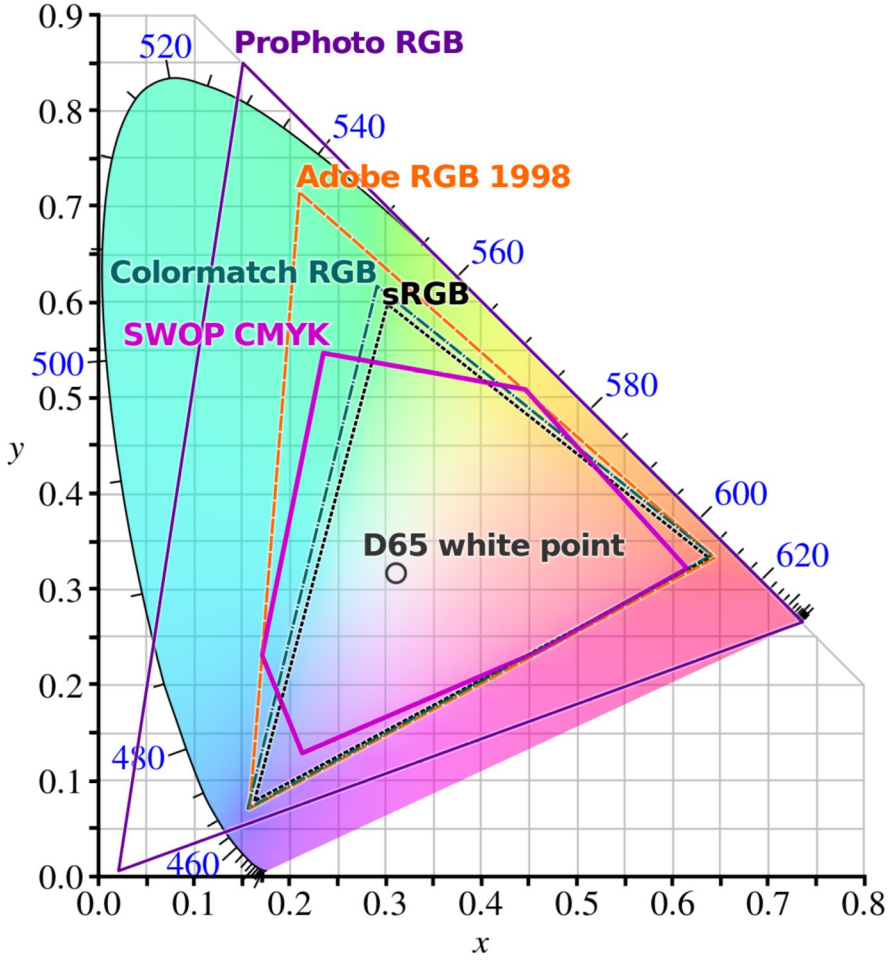
$$R = Y + \frac{1 - w_R}{0.5} \cdot C_r$$

$$G = Y - \frac{w_B \cdot (1 - w_B) \cdot C_b \; - \; w_R \cdot (1 - w_R) \cdot C_r}{0.5 \cdot (1 - w_B - w_R)}$$

$$B = Y + \frac{1 - w_B}{0.5} \cdot C_b$$

GAMUT

- Subset of colors that can be represented



File Formats

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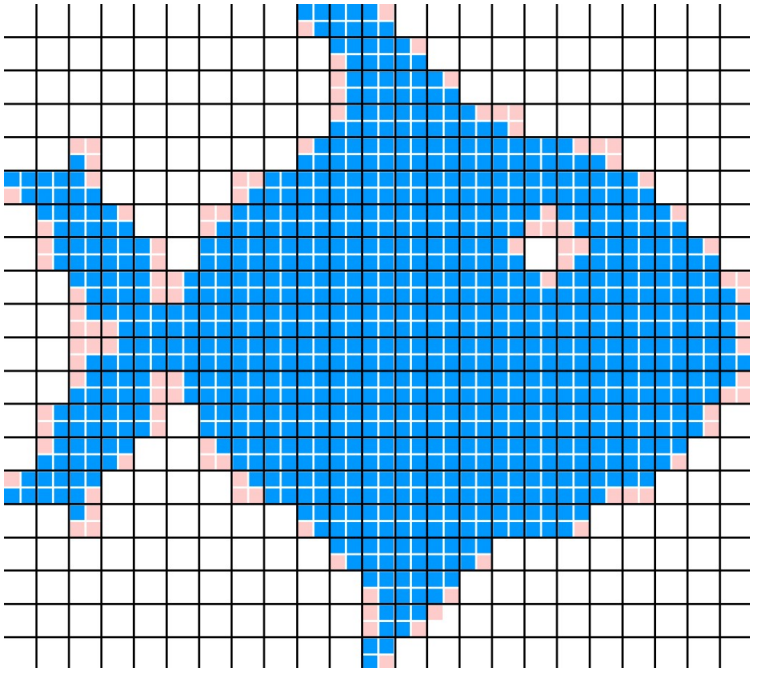
- For raster images, usually:
  - Header:
    - Format
    - Size
    - Color
    - Compression
    - …
  - Bitmap
    - Pixel array(s)



- Every image standard features its own header/bitmap format

PNM also P?M

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- Portable Bit/Grey/Pix Map Format
  - .pbm, .pgm, .ppm
- Uncompressed format
- Very easy to parse
  - In some cases an ASCII editor can be used
- Born in the UNIX Environment
- ASCII Header
  - Format, Size, Comments
  - Comments widely used to encode additional info
- RAW or ASCII bitmap

- Video extension PVM

PNM Header & Bitmap

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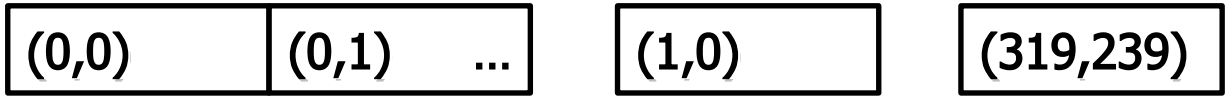
P4 = PBM
P5 = PGM
P6 = PPM

```
P5
320 240
# some free text
255
```

Image Size

Comments (add info)

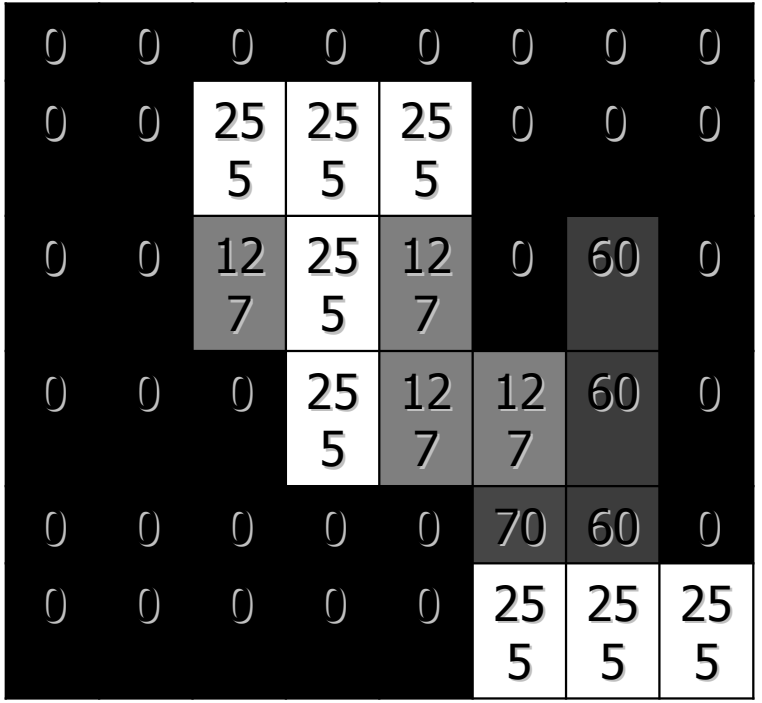
Maximum channel value



PBM, PGM: 1 byte/pixel
PPM: 3 bytes/pixel

- As memory bitmap

0	0	0	0	0	0	0	0
0	0	255	255	255	0	0	0
0	0	127	255	127	0	60	0
0	0	0	255	127	127	60	0
0	0	0	0	0	70	60	0
0	0	0	0	0	255	255	255



Info vs Size

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- The more the information the bigger the memory required
- 4k images
  - $3840 \times 2160 \longrightarrow$ 24 bit color $\longrightarrow$ 23 Mbytes
- Size affects:
  - Memory (this can not be an issue for us!)
  - Storage
  - Transmission

Compressed Raster Images

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- Compression can be mandatory
- Two different policies
- Lossless
  - Original info is preserved
  - Better choice for machine vision
  - TIFF, BMP, PNG, GIF, JPEG
- Lossy
  - Some info is lost
  - JPEG

TIFF Tag(ged) Image File Format

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- Adobe Developers Association,
  - TIFF (TM) Revision 6.0 - Final, June 3, 1992
  - Compresso, senza perdita
  - Compressione:
    - Nessuna, ZIP, LZW ...
  - Profondità di colore variabile
  - Pagine multiple (Fax)

Windows BMP Format

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- Device Independent Bitmap (DIB)
  - Typical extensions are .bmb or, less frequently, .dib
- File structure
  - BITMAPFILEHEADERbmfh;
    - type, size & layout (pixel ↔ lenght)
  - BITMAPINFOHEADER bmih;
    - size, compression and color format
  - RGBQUAD aColors[];
    - Color palette
    - Not present for 24 bit format (24-bit red-green-blue (RGB) for each pixel)
    - Colors are ordered on frequency basis (dithering)
  - BYTE aBitmapBits[];
    - Index or intensity of colors
    - Run-length encoded (RLE) compression

GIF – Graphic Interchange Format

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- Used for web and small animations
- Based on a color palette
  - 8 bit
  - Maximum 256 colors on 16 M max
  - Transparency support
- Patented compression algorithm
  - Big issue

PNG

- PNG coped with patent issues
  - Portable Network Graphic
  - 24 bit depth (~16 millions of colors) + Alpha channel
- “Free” compression algorithm
- No animation support! → this explains why GIFs are still alive..
- 8 bytes initial header (magic number)
  - 89 50 4E 47 0D 0A 1A 0A (as ASCII first four are “.PNG”)
- Other “headers” and data are following as chunks
  - 4 bytes chunk lenght
  - 4 bytes chunk type (IHDR header, PLTE optional palette, IDAT actual data, IEND end of file)
  - Chunk data
  - 4 bytes CRC

JPEG File Interchange Format (JFIF)

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- JPEG: Joint Photographic Experts Group
- Born in the ‘80s
- JPEG is also a compression algorithm
- The idea was to have a platform independent (PC, Mac …) file format
- Can use RGB, CMYK, YUV (maybe others)
- Magic number FF D8 FF

JPEG Compression

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- Compression based on luminance and chrominance
- RGB o CMYK values are converted in $Y'C_bC_r$
  - Luminance + Chrominance
- Y and C_x are separately compressed
- For our eys luminance is more important than colors
  - If a lossy compression is used, Luminance is better preserved
- Compression
  - Image is subdivided in 8x8 pixels blocks
  - Discrete Cosine Transform (~Fourier) is applied to each block
  - Results are quantized
    - Based on assumption the our eye is more sensitive to low frequency changes
    - Basically this wipes our small details

JPEG pros and cons

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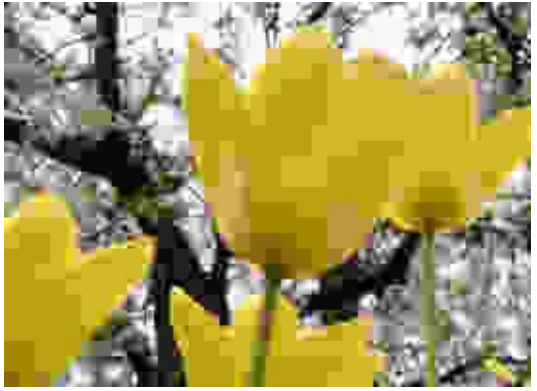
- Different compression levels can be used depending on image usage
  - Up to 20 ⟶ internet
  - Up to 5 ⟶ printed matter
- Good results with images without abrupt changes, namely “low frequency” images
- Bad if sharp color changes
- Avoid, if possible, for machine vision



SVG: Scalable Vector Graphics

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- Vector Graphics
- Described using a language!
  - Based on XML W3
- Different objects
  - Polylines, namely a combination of 1 or more straight and curve lines
    - This allows to obtain all shapes
  - Raster images
  - Text
  - …

SVG: example

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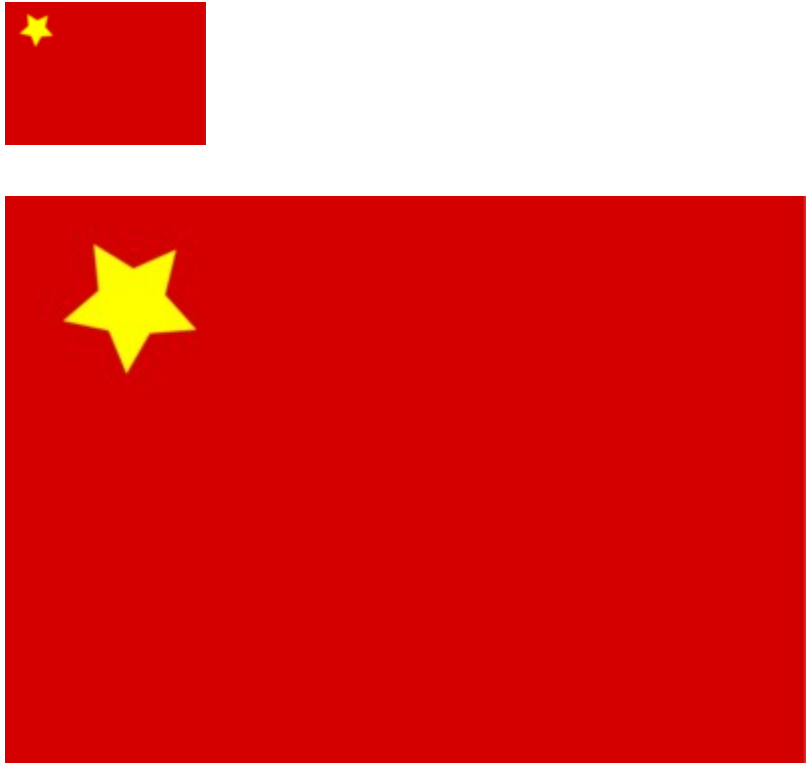
```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<!-- Created with Inkscape (http://www.inkscape.org/) -->
<svg
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:cc="http://creativecommons.org/ns#"
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:svg="http://www.w3.org/2000/svg"
   xmlns="http://www.w3.org/2000/svg"
   xmlns:sodipodi="http://sodipodi.sourceforge.net/DTD/sodipodi-0.dtd"
   xmlns:inkscape="http://www.inkscape.org/namespaces/inkscape"
   width="1052.3622"
   height="744.09448"
   id="svg2"
   version="1.1"
   inkscape:version="0.48.1 r9760"
   sodipodi:docname="Nuovo documento 1">
  <defs
     id="defs4" />
  <sodipodi:namedview
     id="base"
     pagecolor="#ffffff"
     bordercolor="#666666"
     borderopacity="1.0"
     inkscape:pageopacity="0.0"
…
inkscape:randomized="0"
       d="m 251.42858,175.52305 -61.11845,4.77394 -30.71632,53.05434 -
23.42693,-56.65186 -59.949534,-12.81827 46.639804,-39.78672 -6.33453,-
60.976461 52.25191,32.062318 56.03459,-24.867261 -14.34635,59.602324 z"
       transform="translate(0,308.2677)"
       inkscape:transform-center-x="1.8913327"
       inkscape:transform-center-y="6.9973399" />
  </g>
</svg>
```



Point Clouds

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- Not images!
- Set of **data** points in the 3D space
- Free format
  - ASCII is often used
- We will use them sometime

Which format to use for Machine Vision?

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- Not always possible to choose
  - Avoid lossy formats
  - Limited depth formats
  - Quick & dirt approach ⟶ maybe you will have to puchase additional storage
- Not always necessary to choose
  - OpenCV
  - GOLD

File format and memory

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- For processing it is “necessary” to load images
- Bidimensional array seems the straightforward choice
  - But monodimensional structures are widely used
- Carefully consider pixel data
- We will investigate the OpenCV approaches