Computer Graphics

Computer graphics are graphics created using computers and, more generally, the representation and manipulation of image data by a computer.[1]

The term ***computer graphics*** refers to several different things:

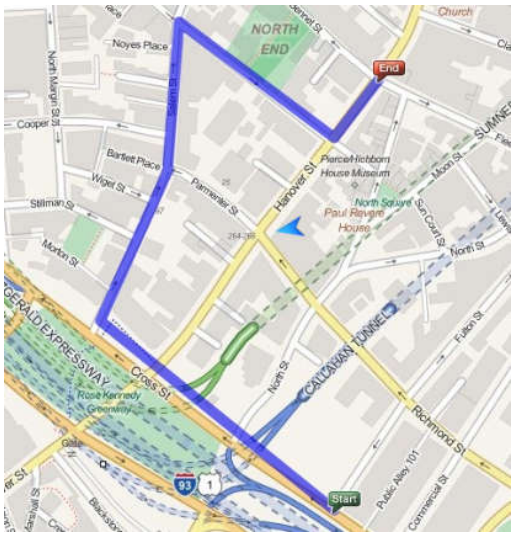
- the representation and manipulation of image data by a computer,
- the various technologies used to create and manipulate images,
- the images so produced,
- the sub-field of computer science which studies methods for digitally synthesizing and manipulating visual content.

Types of processed contents:

I. ***Static 2D graphics*** – representation of two-dimensional scenes – digital photography, cartography, typography, technical drawing …

   a. *Raster graphics*

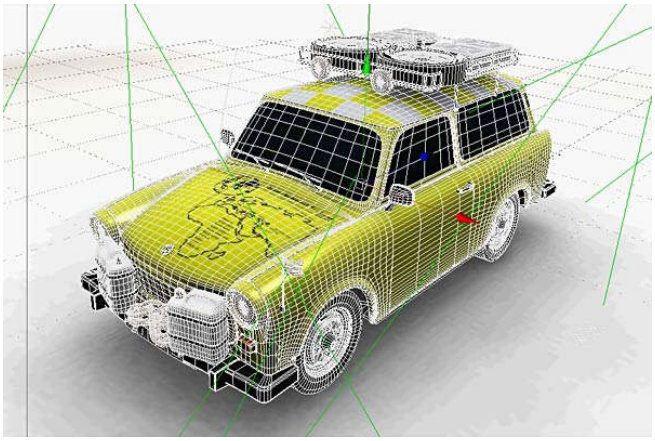
   b. *Vector graphics*



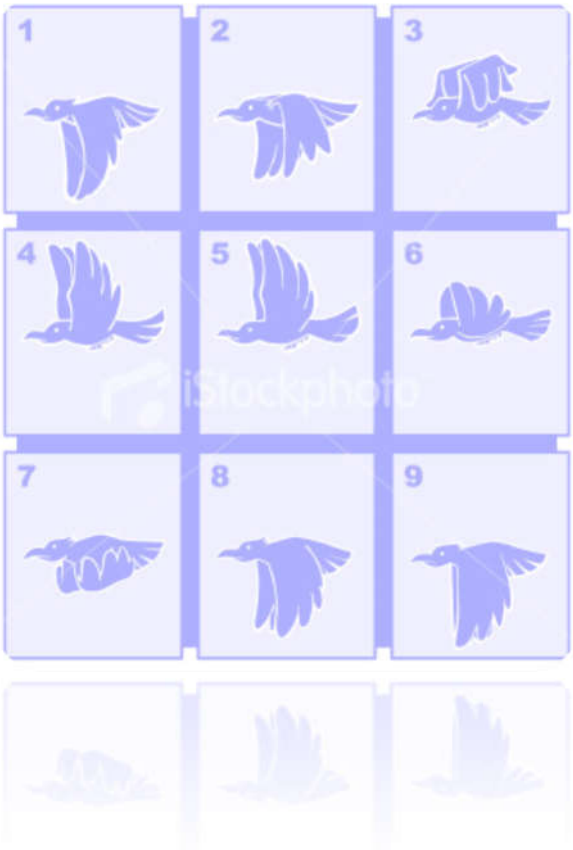
[1] http://en.wikipedia.org/wiki/Computer_graphics

II. ***Static 3D graphics*** – representation of three-dimensional scenes; usually converted to different 2D views. The processing combines both, vector and raster graphics – vectors represent objects of the scene, and the **rendered** 2D scene is stored as a raster picture. **Rendering** is the process (and the result) of generating an image from a model. Below is a rendered image of a Trabant car.

What is rendering? (https://www.youtube.com/watch?v=0Ysc9PViwgM)



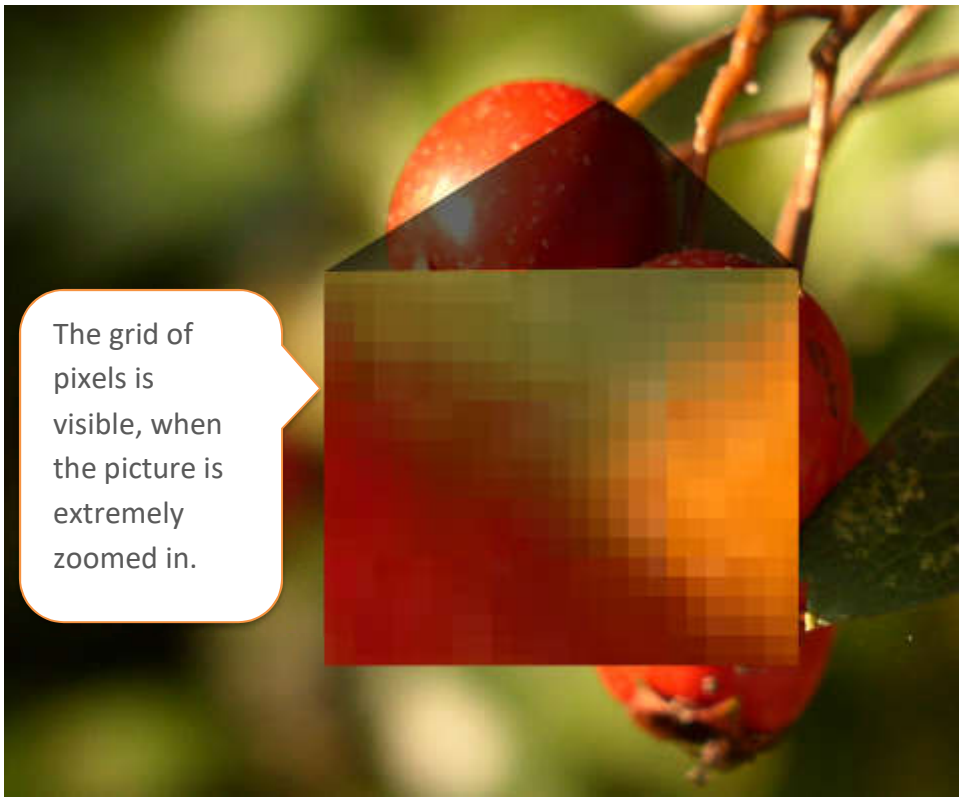
III. ***Animation*** – creation and representation of moving pictures. The most common principle is a rapid display of a series of static pictures – it uses ***phi phenomenon*** – the limitation of human visual perception**.**
The animation can be done in 2D or 3D graphics.



Raster Graphics

Raster graphics are digital images represented by a **matrix** or grid **of pixels** commonly called a **bitmap**. Each pixel or dot displays a unique color and together all of these colored dots create an image. Every pixel in a bitmap is stored as one or more bits in computer memory.

Raster graphics with a greater number of colors and pixels will require more bits and take up more memory. Typical file formats for raster graphics include ***.jpg, .gif, .png, .tiff, and .bmp***.

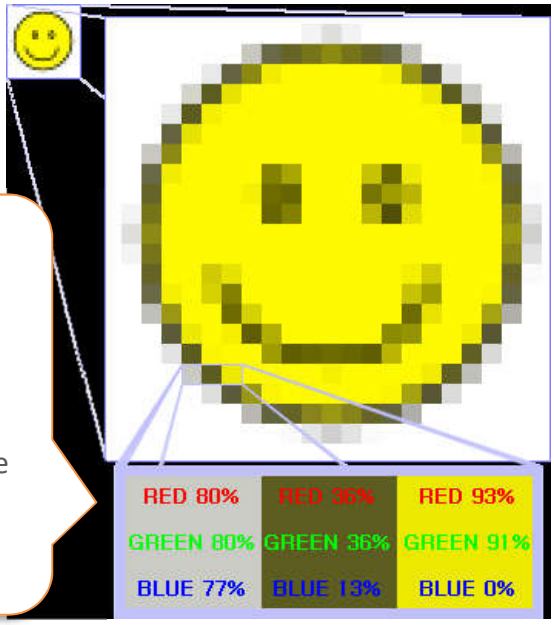


Pixel

It is a single point of a raster image with its colour.

Colour Depth/Bit Depth

Number of colours, which might be potentially used in the picture, is defined by **colour depth** – number of bits for each pixel (e.g. 8-bit depth = 2^8 different colours).



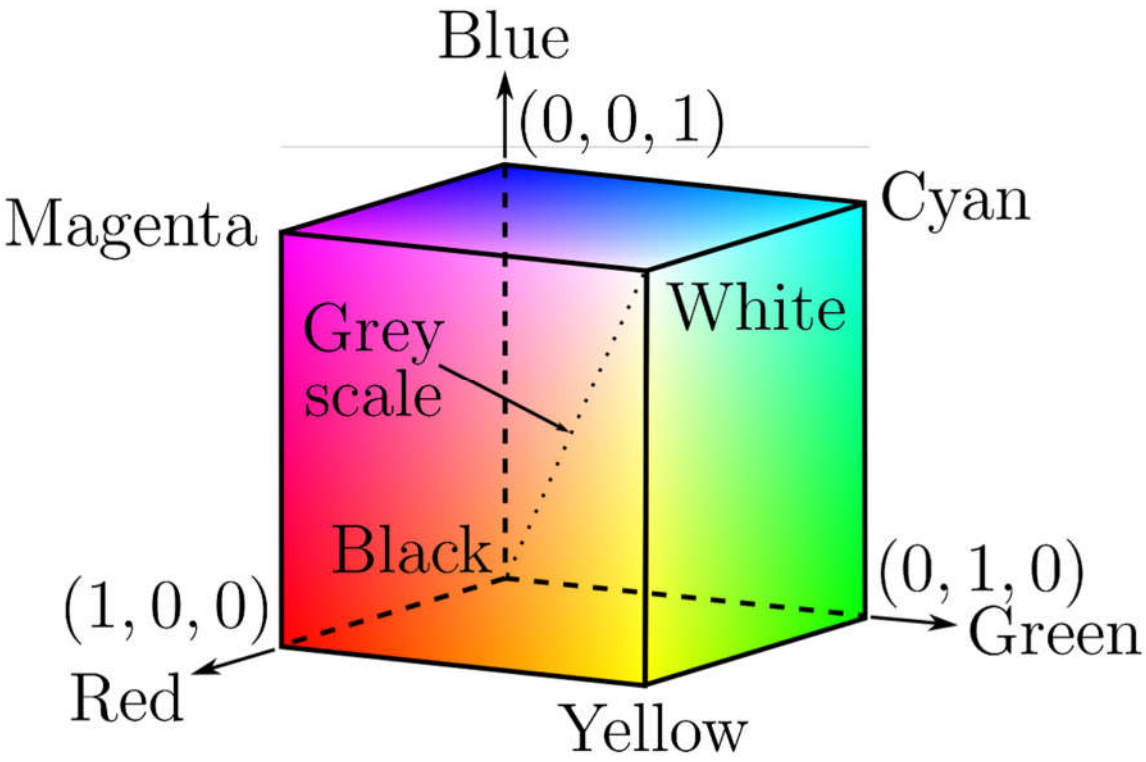
Colour Model

Colour models provide a standard way to specify a particular colour, by defining a 3D coordinate system, and a subspace that contains all constructible colours within a particular model. Any colour that can be specified using a model will correspond to a single point within the subspace it defines.

Each colour model is oriented towards

- specific hardware (RGB - displays, CMYK - printers),
- or image processing applications (HSL).

RGB



Red, **green**, and **blue** are the primary additive colours – i.e. the colours **emitted** for a source of light.

Usage:

- definition of colours for devices projecting light – monitors, displays, projectors,
- definition of colours in webpages.

CMY/CMYK

A complementary model to RGB – for the light reflected from pigments – **colour print**.

Colours: **cyan**, **magenta**, **yellow**, **black**

Conversion:

Cyan = 1 – Red

Magenta = 1 – Green

Yellow = 1 – Blue

Black colour is used to reduce costs of printing – it is cheaper to have independent black ink than to mix colours of 3 inks at maximal intensity to get black (it would not be perfect black nevertheless due to imperfections of real inks). It is also utilised to improve contrast of the printed material.

Colour Gamut

Colour gamut is the entire range of colors available on the device or represented by a colour model.

Although it might seem to be impossible, human eye can recognize more colours than can be reproduced by any known device. The gamut of a device is represented as a subset of the colours perceivable by human eyes.

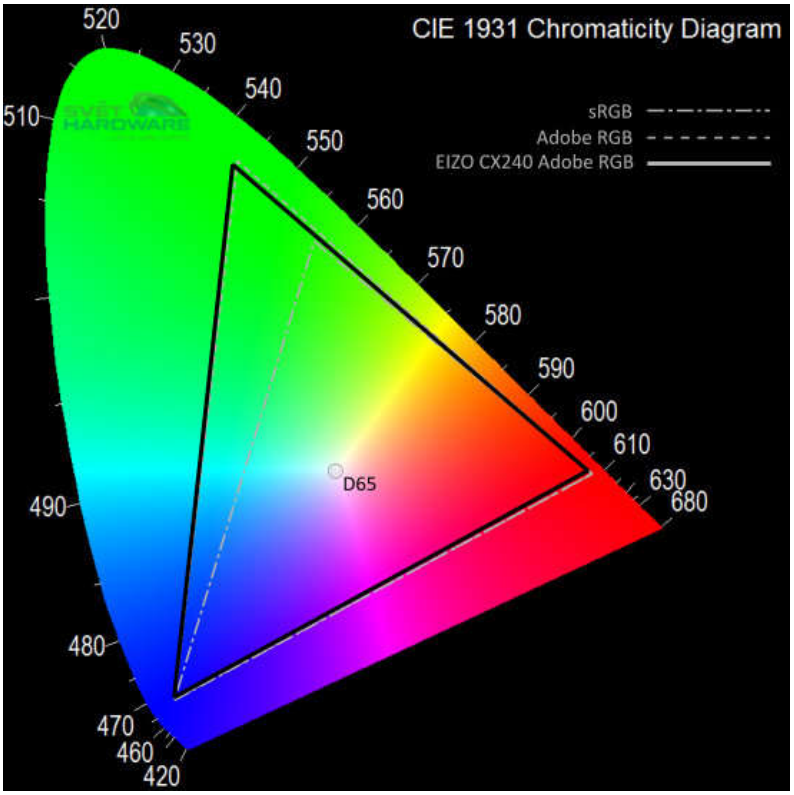


Figure 1:Example of the LCD display gamut – the gamut is represented by the black triangle (source: http://www.svethardware.cz/recenze-eizo-cx240-ideal-pro-narocne-uzivatele/37655-5/img/body-21.35AC/eizo-cx240-gamut-cie-1931.jpg)

The range of colours printers, cameras, scanners, monitors etc. can reproduce varies, so a colour gamut is used to

- make these differences clear

- show what colours these devices have in common.

General rule is the monitors have usually wider gamut than printers; however, there are colours a printer can reproduce in contrast to monitors.

What is Color Gamut? https://www.youtube.com/watch?v=mY-A03-rgX8

Color and Gamut: https://www.youtube.com/watch?v=0AYNOF7gSFg

Resolution

Another attribute defining a raster picture is **resolution**, i.e. number of pixels forming the image. The resolution describes the detail held by a picture.

In general it is expressed by two positive integer numbers – number of pixel columns (*width*) and the number of pixel rows (*height*) – e.g. 640x480.

In case of digital cameras is frequently used total number of pixels forming the final image, typically in **megapixels (width x height / 1 000 000)**.

For printed or scanned images is used another parameter related to the resolution – **DPI (dots per inch)**, which refers to the number of dots (e.g. made by a printer) placed in a line 2.54 cm long.

More correct parameter than the DPI is **PPI – pixels per inch,** since there is no option to set the density of dots the printer uses – it depends on its internal architecture; however, due to historical reasons the DPI is used more frequently with the meaning of PPI.

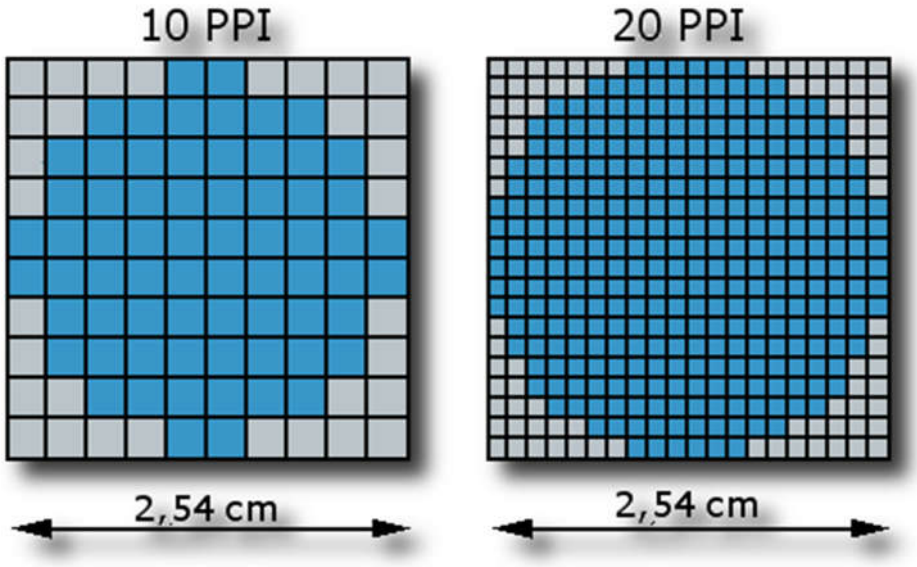


Figure 2: Circle scanned/printed at 10 and 20 (doubled) PPI. Increased resolution brings more details, but it will require 4x more space (source: http://www.fmedda.com/en/article/dpi_ppi).

Vector graphics

Vector graphics (also called **geometric modeling** or **object-oriented graphics**) is the use of geometrical primitives such as points, lines, curves, and polygons, which are all based upon mathematical equations to represent images in computer graphics.

A vector graphics program uses these mathematical formulae to construct the screen image, building the best quality image possible, given the screen resolution. The mathematical formulae determine where the dots that make up the image should be placed for the best results when displaying the image.

Since these formulae can produce an image scalable to any size and detail, the quality of the image is only determined by the resolution of the display, and the file size of vector data generating the image stays the same.

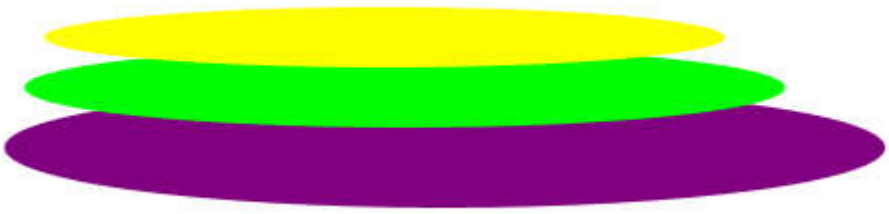
Vector Graphics Files

The standardized types:

- **SVG**
  - *Scalable Vector Graphics*
  - vector format for the web pages and application; however, it became common in different types of applications
  - specific version of the XML → textual, human-readable and editable
  - supports scripting and animations
- **Gerber**
  - Industrial standard for 2D high-precision images (esp. circuit boards)
- **CDR**
  - Corel Draw file
- **AI**
  - Adobe Illustrator file

SVG File – Code Sample

```
<svg height="150" width="500">
  <ellipse cx="240" cy="100" rx="220" ry="30" style="fill:purple" />
  <ellipse cx="220" cy="70" rx="190" ry="20" style="fill:lime" />
  <ellipse cx="210" cy="45" rx="170" ry="15" style="fill:yellow" />
</svg>
```



SVG File – Result

Geometric Primitives

Geometric primitives are atomic elements of the vector graphics, which can be processed by the software and stored in the files. They may vary program by program.

The most common primitives:

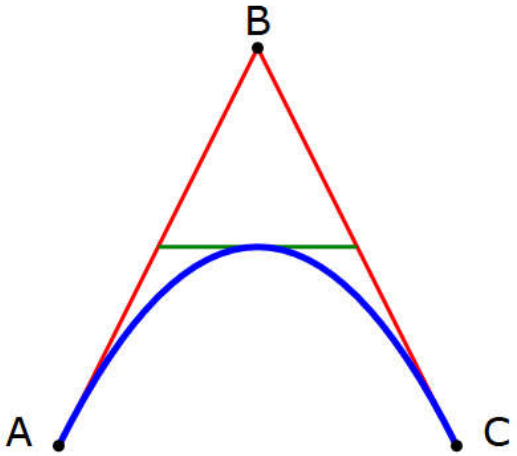
- **lines**
  SVG example: `<line x1="0" y1="0" x2="200" y2="200" style="stroke:rgb(255,0,0);stroke-width:2" />`
- **ellipses**
  SVG example: `<ellipse cx="200" cy="80" rx="100" ry="50" style="fill:yellow;stroke:purple;stroke-width:2" />`
- **polygons**
  SVG example - triangle: `<polygon points="200,10 250,190 160,210" style="fill:lime;stroke:purple;stroke-width:1" />`
- spline curves, esp. **Bézier curves**
  SVG example: `<path d="M 100 350 q 150 -300 300 0" stroke="blue" stroke-width="5" fill="none" />`
- **text** – defined by outline fonts (e.g. TrueType fonts)
  SVG example: `<text x="0" y="15" fill="red" transform="rotate(30 20,40)">I love SVG</text>`

Bézier Curves[2]

Bézier curves are used to model smooth curves that can be scaled indefinitely. Generally, the user selects two endpoints and one or two control points. A Bézier curve with one control point is called a **quadratic Bézier curve** and the kind with two control points is called **cubic**; however, the degree can be any natural number.

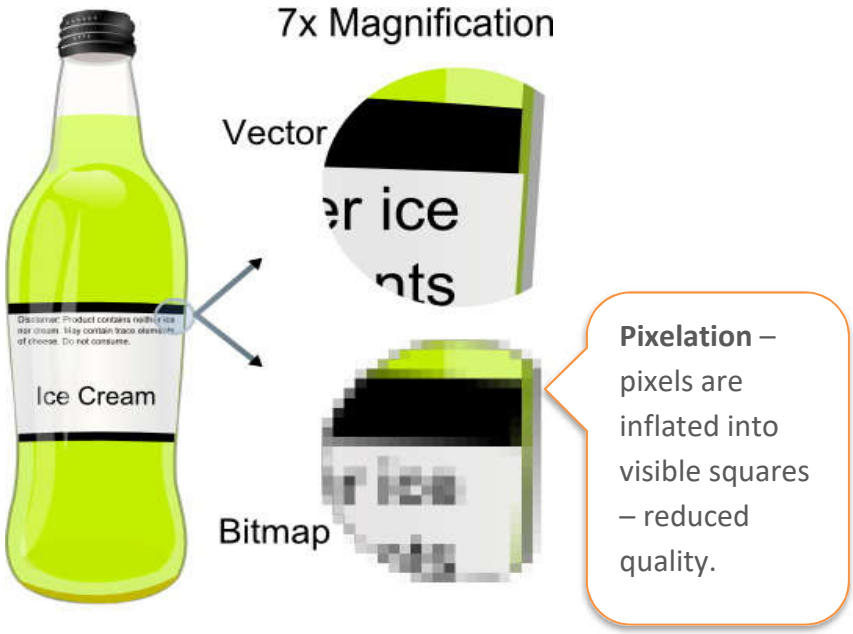
The following picture represents a quadratic Bézier curve, where A and C are the start and end points, B is the control point:

[2] http://www.w3schools.com/svg/svg_path.asp



Comparison of raster and vector graphics (consequently of raster and vector editors)

	Raster Graphics	Vector Graphics
Photorealistic details	+	- difficult; possible when combined with bitmaps (textures)
Size/shape transformation	- **pixelation**	+ no problem, it requires just recalculations of paths
Storage requirements	growing with increasing resolution or color depth, almost independent on image complexity	growing with image complexity, independent on size of the final product



Wordstock

image	obraz
matrix	matica (*obdĺžnikový útvar pozostávajúci z rovnakých elementov*)
pixel	pixel, obrazový bod
graphics editor	grafický editor
raster graphics	rastrová grafika
vector graphics	vektorová grafika
colour depth	farebná hĺbka
resolution	rozlíšenie
pixelation	pixelizácia ("rozštvorčekovanie")
rasterisation	rasterizácia
vectorisation	vektorizácia
optical character recognition	optické rozpoznávanie znakov