Gernot Hoffmann
... What is Computer Vision?

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1 Introduction

What is Computer Vision?
A science - and a lecture by the author

The lecture was initiated by an attempt to describe computer graphics and photogrammetry by the same mathematical nomenclature
Color handling gained more and more importance

Writing down the lecture, it turned out that advanced Paper and Web publishing programs were required

Finally, the lecture Computer Vision contains geometry mathematics, image processing, computer graphics, photogrammetry, color science and media techniques

CV is not a lecture about commercial programs, though we refer often to Photoshop and PageMaker
2 Basic Transformations / Workstation 2D-Transformation

Graphics Elements in a metaplane
Any set of coordinates
Source area by Frame

Graphics Elements in a Device
Printer, monitor or page
Device specific coordinates
Destination area by Viewport

\[ x_v = x_{va} + \left( x_f - x_{fa} \right) \frac{x_{ve} - x_{va}}{x_{fe} - x_{fa}} \]
2 Basic Transformations / 2D-Transformation / Memory Mapping

Destination framebuffer is RAM or VRAM (Graphics Card)
Source framebuffer is RAM
Isometric by camera position at infinity, a mathematical construct
Normal by natural camera position, perspective projection
Rectified by natural camera position and tilted image plane
4 Photogrammetry / Video Motography

Observe four light emitting diodes by two video cameras
Calculate LED positions by photogrammetry

Copy human dancing motions to a computerized life size marionette
Teaching a robot by showing the motion
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5 Color Systems / RGB Cube / HLS Doublecone / Physical CieLab Space

- RGB Cube
  - Cyan
  - White
  - Magenta
  - Green
  - Yellow
  - Red
  - Black

- CieLab
  - L*
  - a*
  - b*

- Hue / Lightness / Saturation Cone

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5 Color Systems / CIE Chromaticity Diagram

Illustration of visible colors in a plane x, y
RGB gamuts are represented by triangles

Volume of visible colors in XYZ coordinates

Based on color matching principles by H. Graßmann

Gamut for NTSC Primaries
Gamut of a standard screen ITU-R BT.709 phosphors
Gamut for CIE Primaries
Corners on the contour

Dominant wavelength in nanometers

Purple line
6 Color Management / Consistent Colors in Product Development

<table>
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<th>Industrial Products</th>
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<tr>
<td>Pantone Film / Foil</td>
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Integrate swatches and samples into a computer controlled workflow.
Colors are measurable by instruments – but perception is subjective.
6 Color Management / Workflow

Calibrate Monitor
- by Hardware
- by Adobe Gamma
- by Instrument

Calibrate Printer
- by Instrument

Define Working Space

Optimize Images by appearance on monitor

Result
Working Space RGB-Data which refer accurately to physical colors
6 Color Management / Monitor Calibration

Web document caltutor270900.pdf / Adjust your monitor

Hardware Monitor Calibration

Luminance L(R,G,B)

1.0 (255)

Luminance = (Brightness + Contrast · N)^Gamma

- Let your monitor warm up one hour
- Adjust Contrast to maximum
- Adjust Brightness for Black
  Brightness is not used for White
  A black rectangle should be visible (arrow)
- Adjust Contrast for White luminance
- Try to balance all colors until the Grayscale shows no tint of any color
- Shift to red gray: Standard D65 6500 K
  Shift to blue gray: Standard Monitor 9300 K

This image should show natural colors

Gamma Test Patterns

2.0 2.2 2.4
Equal Gray for inner and outer square
Adjust Gamma = 2.2
Use Zoom 100% or 200%
Browsers are not accurate
Please download and view by Acrobat
6 Color Management / Printer Calibration

Print about 1000 color patches
Read patches by Spectrophotometer
Build color correction table /ICC Profile
Result: print is as accurate as possible

ICC Profiles are valid only for a specified process
- Printing machine
- Actual ink cartridges
- Paper or other media
- Resolution
- Dithering mode
- Ink limit setting
- Dark/light ink transition
- Undercolor removal
- Rendering Intent

High quality printing programs are called Raster Image Processors (RIPs)
We use Onyx PosterShop Pro and Best Colorproof

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Rotation, scaling, morphing and perspective rectification require subtle interpolation algorithms
7 Image Processing / Geometry / Morphing

Perspective rectification
Four lines, one mouse click

Morphing
Circle shows affected area

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7 Image Processing / Light Effects

Light effects by simulating the illumination of a paper photo by lamps

Artificial color illumination for the glass sphere and the cube     Darker environment and soft white light

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7 Image Processing / Filtering

Retouch
Sharpening
Sky segmentation

Contour
Sometimes used internally for edge enhancement or softening
8 Computer Graphics / Textures

Subdivided icosahedron
Single icon mapping
Facetted shading

Subdivided icosahedron
Multiple icon mapping
Gouraud shading
9 3D-Scanning

Our scanner
Turntable and lift
Range by triangulation, using a single row CCD camera

Scanner construction by Toni Gosling
Graphics by ZEFIR
9 3D-Scanning

Industrial scanner Cyrax 2500
Scanning the Hagia Sophia
A project by Prof. Dr. Volker Hoffmann
Institute for History of Art / University of Bern / Switzerland

Hagia Sophia in Istanbul
Church / Mosque / Museum
Built 532 – 537

Laser beam deflection
by two-axis mirror
Range by light runtime
10 PostScript Workflow

PostScript is a page description language

A page consists of
- Vector graphics: lines / boxes / curves / circles
- Text: a special kind of vector graphics
- Raster graphics: photos or computer graphics

PostScript guarantees
Consistent workflow between desktop publishing programs PageMaker / InDesign / Quark XPress and printers

PostScript printers
Receive all necessary data for a page
Build the page by an internal high speed processor
Calculate the CMYK color pixels for the printing

Use PostScript PDF for documents
Use PostScript EPS for single pages
Use BMP or TIFF for single raster images
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Author
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R.Scherge (14,17)
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Sculpture (18) and plaster head M.Hoffmann
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