# **Gernot Hoffmann**

# **Computer Vision**

# **Documents for Students**

**Table of Contents** 

Part 1 Covi-Org

Organization

# Part 2 Covi-Intro

Projects

Content of Lecture

References

Web tutorials

Teach-In of a Robot by Showing the Motion

Tables

**Raster Tester** 

Part 3 Covi-Lab

Laboratory Exercises (practicals)

#### Part 4 Covi-Bild

**Graphics Collection** 

September 15 / 2005

Please print everything as grayscale and replace at least these pages by color prints: Covi-Lab: 15, 16 Covi-Bild: 16, 18, 19, 20,35, 38

#### **Exercise No.1**

# Windows and Frames, Projections

#### 1.1 Windows and Frames

# Load RESPONS

many text windows ?		
0	Bitte uarten ESC Zurück	
	t/s 10.00	
	Grafik drucken:	
t) 0		
	g1         0           k2         0           g2         0           k3         0           g3         0	
y1 y2 y3 ↑ ↑ ↑	3 y4 4 y1, k2, k3 Koordi. 9 y1, g2, g3 Geschu, 1 y1 y2 1 y1 y1 1 y1 y2 1 y1 y1 1 y1	
ion: 29.10.97 Prof.Dr.6.Hoffmann + W.Kettui m: 09.09.103 Constantiaplatz 4 26723 Emc	ig T: Iden	

		xwA	ywA	xwE	ywE			
1	Bottom right							
2	Signal flow							
3	Function							
Assign Fram	o Coordinatas ta th							
0	te Coordinates to the	e windows xfA	vfA	xfE	vfE	x-Unit	v-Unit	
1	Bottom right	e windows xfA	yfA	xfE	yfE	x-Unit	y-Unit	
1 2	Bottom right Signal flow	e windows xfA	yfA	xfE	yfE	x-Unit	y-Unit	

Derive the relation between Frame coordinates xf, yf and Window coordinates xw, yw. Derive the relation between Window coordinates xw, yw and Pixel coordinates xp, yp.

#### 1.2 Projections

Make a drawing (sketch) which shows the object space, the image plane and the camera. Show the camera position, the viewpoint and an object point. Show the mapping of the object point to the image plane. Derive the equations, assumed the camera rotation matrix C is given.

#### Load ZEFIR



Why is the visible camera called 'Internal Camera' ? What's the 'External Camera' ?

Show the internal camera position and the viewpoint. Select Internal / Camera+Light / Camera Move the internal camera arbitrarily and observe the image top right. Move the camera towards the object. The image size remains the same. Discuss this phenomenon.

Change the zoom of the camera. The image size changes. Discuss this phenomenon.

SelectObject / Type / CubeSelectInternal / Camera+Light / CameraFind a camera position with undistorted verticals. Describe the relation between camera and object.

Move the camera upwards. Select Vertical Rectification Move the camera further upwards until some parts of the object are invisible. Move the viewpoint and eventually the zoom until the object is completely visible. Move the camera. Do we still have vertical rectification ?

Select Object / Sphere. Describe the contour of the sphere

Select Internal Camera+Light /Camera / Central Projection Now we have no rectification. Describe the contour of the sphere.

 Select
 Default / Internal

 Select
 Default / Object

 Select
 External / Camera+Light / Camera

 Move the external camera until the ground plane appears flat.

 Walk with the external camera around the scene. Which types of graphics elements are visible?

Move the external camera upwards. Which additional graphics elements are visible ?

Select Default / External Select Internal / Camera+Light / Camera Move the internal camera. Which geometrical transformations, regarding both cameras, are necessary for the generation of the 2D screen content ? Select Default/Internal

Make a sketch of the 'Aircraft Rotation' gimbal system.

- $\psi$  = Yaw = Gieren  $\theta$  = Pitch = Nicken
- =
- $\phi$  = Roll Rollen

Select	Object / Type / Cube
Select	Object / Rotation
Object rota	tions are in ZEFIR defined in 'Aircraft Angles'.
Show sma	Il rotations about each axis separately.
Yaw angle	e about axis
Pitch angle	e about axis
Roll angle	e about axis

Rotate first Yaw=+45° and then Pitch=+30°. Make a fast sketch of the orientation

Rotate both angles to zero. or use

Rotate first Pitch=+30° and then Yaw=+45°. Compare the two orientations. Which result ?

Now assume, the gimbal (Rahmen) sequence in the Aircraft Rotation is swapped, e.g. like the Gyro Rotation. Would we get the same orientation?

Select Object / Type / Cube Internal / Camera+Light / Camera Select Select Parallel Projection Move the internal camera. Where is the camera geometrically located ?

Move the camera until an isometric projection is achieved. What does this mean ?

Strong definition

Practical definition

Move the camera until a Cabinet projection is achieved. Draw a Cabinet projection of a cube.

Obviously it's impossible. What's the reason ?

SelectDefault / InternalSelectInternal / Camera+Light / CameraChange the camera roll angle. Observe the camera case and the image top right. What happens ?

#### Photogrammetry

#### 2.1 Understanding Photogrammetry Applications

Read the publication 'Teach-In of a Robot by Showing the Motion'. Make a list of words English-German as far as necessary. Try to explain the main principles (not necessarily the complete mathematics) by your own words in German (extra page).

#### 2.2 Preparations (not for students)

Power OffRucksackConnect Load Cable from ExTrac to Rucksack.Power OnExTracLoad Battery several hours.Power OffExTracRemove Load CableAssemble black Calibration Frame.Disconnect cable XT1f.Connect cable LT1f-LT2f from ExTrac to Calibration Frame.Connect cable LT3f-LT4f on Calibration Frame.

#### 2.3 Motography using ExTrac

Power OnExTracLoadEXTRACSelectSETUP / Laden / Para5Led.Ext / OKSelectMESSUNG / Online / StartCheck the function with a lighter.What are the two graphics windows showing ?

Explain the function of ExTrac.

#### Select EXIT

#### 2.4 Calibration of Two Cameras

Explain the laboratory coordinate system which is defined by the Calibration Frame, using a sketch.

Load HOKAMERA Start measurement. The window bottom right shows 11 camera parameters. Parameters k1 and k2 concern the correction of lens distortions. Interprete the other 9 parameters with respect to the real Camera 1. Which one is Camera 1 ? Start Measure Camera 1 The window top left shows 10 values R,T . These are point coordinates in the camera coordinate system. iWhat do they mean ?

Start Optimization Camera 1
The window top right shows the actual parameters.
Observe the number of iterations and the error square sum.
It may happen that the error square sum ist not small. What can be the reason ?

Which optimization method is used ?

Explain the method using a sketch.

Stop	Optimization	Camera1
Start	Measure	Camera 2
Start	Optimization	Camera 2
Stop	Optimization	Camera 2
Start	Rückrechnung	

Explain the expression 'Rückrechnung'.

Explain the shown three triples of LED-1 coordinates:

Continue step by step up to LED-5 Estimate the mean uncertainty in 3D of the measurement.

Which uncertainty is to be expected if the observed object points are far away in y-direction ?

Start Radien A radius rik is the distance of object points Pi ,Pk for LED-1 to LED-5. What may be the reason that we show also the radii ?

Quit

#### 2.5 Motography Rucksack

Power OffExTracRemove cable LT1f.Connect cable XT1f.Power OnExTracLoadMOBMOTSelect3DPower OnRucksackStartMeasure

Explain the function of the Rucksack.

Which kind of projection is used on the screen ?

Find Rucksack positions with uncertain measurements. Where is the accuracy very bad ?

How is the the Rucksack used for Teach-In of a Robot ?

How can we reconstruct smooth trajectories of the moving person ?

The trajectories belong to a kind of dancing, synchronously to music. The playback needs the same music. How can we achieve a synchronous start ?

How can we achieve a synchronous run despite the fact that the actual audio system may run slower or faster than during the Teach-In ?

The servo mechanisms of the marionette are on purpose slowed down to achieve a smooth run. How is the delay compensated ? The smoothed trajectories are not sent in time (zum vorgesehenen Zeitpunkt) to the servos.

Power OffRucksackPower OffExtracPower OffPC

#### Exercise No.3

# **Scanning and Color Models**

# 3.1 Scanning of Rastered Monochrome Prints

The image was scanned, smoothed and artificially rastered by a program. The effect can be shown only by a high resolution printer (tested by a laser printer with resolution 1200 dpi ).



Pierre Leprohon: Michelangelo Antonioni, Der Regisseur und seine Filme Fischer Verlag, Frankfurt/M, 1961

Raster Testers can be purchased by prepress suppliers. Our testers were programmed in PostScript and printed on film with 2800 dpi.

Measure the raster frequency in Lpi (lines per inch, also called Rasterweite in Lpc (Linien pro cm) and the raster angle in degrees:

Offset and laser printers print raster cells in Lpi-distance, which are filled with dots in dpi-distance. How many gray levels can be generated for this example (Lpi = dpi/10)? Formula ?



This leads to the thumb rule Lpi = 0.1 dpi. This is roughly valid for printers with at least 600 dpi resolution (600/54, 1200/106). More than 256 levels are not required.

#### **Primary Aliasing:**

Scanning an already rastered image will cause mostly artifacts, Moiré patterns, because of interferences between the raster frequency and the scan frequency. Primary Aliasing cannot be cured by Image Processing.

Secondary Aliasing:

If the image was scanned with high resolution (the printed spots are visible in the scan) then we will get artifacts in the scaled or rotated image.

What's to do ? Either scan with a synchronized resolution or scan with high resolution and smooth the scanned image.

Load ZETSCAN

This is a simulator for showing effects on scanning rastered monochrome pictures. The Measured Raster Frequency is rfm=100 dpi - just an arbitrary value for the simulation.

Recommendations for scanning already rastered pictures:

Measure the raster frequency rfm and the raster angle a. Calculate the Effective Raster Frequency rfe. rfe = rfm cosa for a = 0°, 15°, 30°, 45° rfe = rfm cos (90°-a) for a = 60°, 75° Use the Effective Scan Frequency sfe = rfe Execute Result ?

```
Now rotate the raster to a = 45°
sfe = rfm = 100
Execute
Result ?
```

sfe = rfe = 71 Execute Result ?

sfe = 1.5 rfe. The scan should be better because of higher resolution. Execute Result ?

sfe = 4 rfe Execute Result ?

What is to do in Image Processing for this overscanned image ?

Quit

Monica Vitti und Alain Delon in L'Eclipse von Michelangelo Antonioni



Rasterfrequenz 54 Lpc 137 Lpi Rasterwinkel 45° Effektive Rasterfrequenz 97 dpi

There is no visible primary aliasing. Why was this picture scanned with the effective scanner frequency sfe=97 dpi?

Load E:\Covi\_250.bmp Select Geometry / Scale=2 Scanned by 250 dpi. Can you see primary aliasing ? Explain.

Load E:\Covi\_388.bmp Scanned by 388 dpi. Can you see primary aliasing ?



Select Geometry / Scale Scale up and down. You will see secondary aliasing. Explain.

SelectScale =1SelectFilter / Soft / ExecuteSelectGeometry / ScaleScale up and down. Can you see secondary aliasing ? Explain

#### Quit

Resumed:

Scanning with the effective raster frequency will produce no primary and no secondary aliasing. Scanning with four times the effective raster frequency saves a maximum of information. Then Soft Filtering is essential to avoid secondary aliasing.

Scanning with two times the effective raster frequency looks good, but then the image is extremely sensitive to a tilt angle during scanning.

Scanning with odd frequencies (krumme F.) produces primary aliasing.

Printed color pictures should be scanned with a rather high scan frequency, e.g. 600 dpi .

After Soft Filtering and Scaling to the final size (number of pixels in each direction) the original large file can be deleted. Quality Images are never made for only one printer. Thus the scan frequency should not depend on the printer.

#### 3.2 Color Models

#### 3.2.1 CIE-Model

Draw a sketch of the CIE Chromaticity Diagram and explain. How is the color volume XYZ mapped to the xy plane ?

Where are the brown colors ? Where is black ? What is a white point ?

#### 3.2.2 RGB-Model and HLS-Model

LoadZEBRAALT+CColor ModelsSelectScreen CalibrationWhy is the circle not elliptic ?



The image shows fully saturated colors and grayscale patterns. Why is the lightness on a radius on the color wheel not equal ?

The mode is True Color. How many colors are possible altogether ?

How many colors can the screen show in one image (Px x Py pixels, here 1280 x 1024 pixels)?

Select RGB-Cube Precision

- Select Graphics Patter / Grid
- Select Projection Type / Central Perspective Rotate the RGB-Cube.

Make a sketch of the RGB-Cube with all axes in standard orientation. Show saturated R,G,B. C,M,Y and the gray axis.



Select Foley HLS-Cone Rotate the Cone.

Make a sketch of the Foley HLS-Cone with all axes. Show fully satured colors and the gray axis.



Select Hoffmann HLS-Cone Rotate the Cone.

Make a sketch of the Hoffmann HLS Cone with all axes. Show fully satured colors and show the gray axis.



ESC Color Models Select RGB-Cube Tutor Here we see cross sections and views from outside. Where are fully saturated colors R,G,B,C,M,Y ? Where is Black and White ?

ESC Color Models

Select HLS-Cone Tutor Here we see cross sections and views from outside. Make some experiments.

Find color values 0...255 for fully saturated R,G,B,C,M,Y with Lightness L = 1.

Find color values 0...255 for half saturated R,G,B,C,M,Y with Lightness L = 0.5. Draw a sketch. You should be able to navigate in HLS.

Why is the image of the sky not affected (erased) by the Cube ?

ESC Measure Cubes per second.

Select	RGB-Cube Animated
Select	Drifting Color Space
Select	Vertical Synchronization

What happens ?

ESC Measure Cubes per second

Quit



# Image Processing: File Operations and Geometry

#### 4.1 Basic File Operations

Loaded images are handled by 32 bit and stored as BMP-32. The fourth byte is called 'palette byte', actually used for selected areas in an image and for default palette colors. Grayscale image can be stored BMP-8.

Zebra Images are stored in Image Banks with 5 letters and 3 numbers like D:\Image000.BMP ... D:\Image999.BMP F:\Eva\_000.BMP ... F:\Eva\_999.BMP Up to 100 Image Banks are defined in ZebraCFG.PAS .

A scanner image may be stored for an existing Image Bank, e.g. D:\Photo200.BMP using BMP-24 (16.6 Millions of colors) or BMP-8 for grayscale images (256 grays). When ZEBRA is started, this new image will be found automatically and delivers a catalogue entry D:\#CAT\Photo200.CAT, which is a 10% thumbnail.

The catalogue - up to 100 thumbnails - is shown by F9, and an image is selected by a Left Mouse Click. It is not possible to load an image from a subdirectory like D:\Myname\Photo200.BMP.

ZEBRA can load images up to (8x1280) x (8x1024) Pixels. Such an image is downsampled for (2x1280) x (2x1024) by computing mean values.

For this size some Geometry operations and Soft Filter can be applied. Finally the image has to be downsampled to 1280 x 1024 Pixels. All ZEBRA Images are handled with this size for further operations.

An Image up to 1280 x 1024 is called Normal Image. An Image up to 2560 x 2028 is called Large Image. An image exceeding this size is called Oversized Image. Oversized Images are loaded Large. Large Images must be downsampled to Normal.

Two arbitrary images can be tagged by F1, F2 and loaded by F3, F4.

#### 4.2 Geometry

#### 4.2.1 Translation, Rotation and Scaling

Load Load	ZEBRA E:\Covi_400.bmp
Select	Image Processing / Geometry
Select	Scale Try different stepsizes. Scale shows a fast preview.
Select Shift	Translation left, right, up, down Try different stepsizes

Finally back to original position.



Select Rotation Select Stepsize +10° Execute by Cursor. The monitor shows a fast preview. Discuss the shape of originally sharp edges.

# ESC Select Interpolation Method (one after the other, no Undo) Describe results Nearest Neighbour Bilinear Biqudratic Bicubic B.Spline

ESC ZEBRA Main

#### 4.2.2 Perspective Rectification

Load	E:\Covi_406.bmp
F1	Tag Image

ZEBRA shows original pixels, here only the center part of the house. What's the reason, especially for scanned raster prints ?



Select Select	Image Processing / Geometry Scale Downscale until the house is completely visible.	
Select	Perspective Rectification	
	Mark the façade of the house by 4 mousel	ines, finished by the fifth Left Mouse Click.
ENT	Execute	-
Select	Scale or Translation alternatively	
	Adjust until the house has the appropriate	size
ESC	Leave Geometry which results in Cut to So	reensize
	If the Perspective Rectification was not such	ccessful then repeat by

F3 Reload the same image

Make a sketch of the Perspective Rectification, showing the original façade and the rectified façade.

Which mathematical algorithm is used for this procedure ?

Write down the basic equations for this kind of mapping a flat image to a flat image. Source image coordinates are x,y. Destination image coordinates are f,h.

The Perspective Rectification of the façade does not necessarily show the correct aspect ratio like in the real building. Draw two different alternatives of the Perspective Rectification.



Which additional information is necessary to reconstruct the original aspect ratio ?

ESC Zebra Main

#### 4.3 Segmentation

A part of the image should be isolated and marked by a specific 'Palette-Byte', which is the fourth byte for each pixel. In Computer Graphics this means really one of 256 predefined Palettes, whereas in Image Processing. the color can be left the same as originally or modified by HLS or RGB. Thus we can say a Palette is here merely the index of a segmented part. In Photoshop it's called a selection.

#### 4.3.1 Segmentation without Fixed Zoom (Lupe)

Load	E:\Covi_400.bmp (Market)
F1	Tag Image
Select	Image Processing / Polygon Cut
	Cut contour of top yellow bucket. Use many points at sharp corners
Select	Close
Select	Toggle
	Toggles between Polygon and Spline Interpolation
Select	Spline
Select	Outside Transparent
	Assign new free Palette by click on segment
ESC	Writes to Buffer automatically

ESC F3 Select L ? ENT ESC	Zebra Main Reload Image Image Processing / Retouch / Copy Load Segment Find original position. Assemble segment ( or Left Mouse Click ) Zebra Main
Select	Image Processing / Color Move MouseFrame to bucket and check Palettes. PLS_(Palette HLS)
ENT ESC Select	Adjust a red color with some blue like the other red buckets. Execute FullScreen Zebra Main Store to Disk Write to Disk with new number D:\Image901.BMP.
ESC	Zebra Main
4.3.2	Segmentation using Fixed Zoom
F3 Select	Reload Image E:\Covi_400.bmp Image Processing / Geometry / Zoom / Fixed Zoom / 4 Move MouseFrame to top yellow bucket.
ENT ESC	Execute FullScreen Zebra Main
Select ESC	Image Processing / Polygon Cut Cut contour as above. Outside Transparent. Assign new Palette by click on segment. Write to Buffer
Y ESC	Assemble Image Zebra Main
Select ENT Select	Image Processing/Geometry/Zoom/Rescale Fixed Zoom Assembles Segment in original image in original size. Store to Disk
ESC	Zebra Main
Select	Image Processing/Zone Cut Position mouse in bucket Cut segment by Left Mouse Click
Select ESC	Outside Transparent The Segment is again isolated and written into a copy buffer, thus available for any Retouch Zebra Main
Select Select	Delete Y Deletes the conv D:\Image 901 BMP
ESC	Zebra Main

Explain the Spline Interpolation for the polygon by a sketch



Fixed Zoom uses bilinear interpolation.

Fixed Zoom = 2 inserts 1 Pixel linear

Fixed Zoom = 3 inserts 2 Pixel linear

Fixed Zoom = 4 inserts 3 Pixel linear

Explain for Fixed Zoom = 2, drawing  $2x^2$  adjacent original pixels and the new  $3x^3$  pixels.

Explain for Fixed Zoom = 3, drawing 2x2 adjacent original pixels and the new 4x4 pixels.

Outside Transparent uses a Contour Tracker. The contour is defined by the change of Palette byte P . Try to explain the tracking of a contour.



#### Exercise No. 5

#### Image Processing: Filters, Retouch and Distortions

#### 5.1 Filters

Filters can be local or global. Local filtering is here called Retouch.

#### 5.1.1 Practical Filter Applications

Load	ZEBRA
Load	E:\Covi_400.bmp (Market)
F1	Tag Image
Select	Image Processing / Filter
Select	Soft
How does a	a Soft Filter (blurring filter, Gaussian blur, Weichzeichner) work?

Select Hard How does a Hard Filter (sharpening filter, unsharp mask, Hartzeichner) work ?

SelectUndo or F3SelectContour Filter with different Blend factorsHow does a Contour Filter work ?

SelectUndo or F3SelectAnti AliasingHow does an Anti Aliasing Filter work ?

# ESCZebra MainLoadE:\Covi\_500.bmpSelectImage Processing / Filter / Zone Boundary Soft

How does this Filter work?



ESC Zebra Main

Load E:Covi\_510.bmp F1 Tag Image Select Image Processing / Extra Filter / Negative

How does the Negative Filter work ?



Selext	Extra Filter / Black+White 1/3 -Matrix
ESC	Zebra Main
Select	Image Processing / Retouch / Copy
	Adjust large Mouseframe about 100mm x 100 mm
W	Writes content to buffer
F3	Reload Image
Select	Extra Filter / Black+White YIQ-Matrix
ESC	Zebra Main
Select	Image Processing / Retouch / Copy
L	Load content of Buffer and copy

How do these filters work ? Which differences can we observe between two Black/White conversions ?

ZEBRA contains also an accurate Photoshop Black+White conversion which applies additionally a Gamma correction. Furtheron some Effect Filters in Mode Extra Filter (Pencil, Chalk, Posterize).

#### 5.2 Retouch

Retouch means local manipulations in an image. An area is picked up, scaled, rotated and eventually modified in lightness and colors and then applied at the same or at a new position.

Two modes for picking up are used:

- P Pick up, for use in the same image.
- W Write to Buffer, for use in the same image or in in other images.
- L Load loads the buffer content

An area can be copied uniform or fading. Fading means a continous transition to the environment. In some applications a blend factor is available. blend = 0 to 1 means increasing the effects. Fundamental experiences show that an image cannot be retouched by painting. It is always necessary to apply similar areas to the retouch areas because of the internal textures.

#### 5.2.1 Practical Retouch applications

Load ZEBRA Load E:\Covi\_520.bmp This is a raw digital photo. Select Image Processing / Retouch / Gauss

Try to clean the skin and to remove flash reflexes by Gaussspray and Soft. How does Gauss work ? (C.F.Gauß)



Select Rough Grain

Too much Soft Filtering may produce unrealistic smooth surfaces. How does Rough Grain work ?

The next experiments can be performed without practical use in this image

Select Hard Apply several times.

Why is the result unsatisfying ?

Select Copy Uniform Apply. Select Copy Fading Use different Blend Factors.

Describe Copy Uniform and Copy Fading, using a sketch

# 5.3 Distortion (Morphing)

Distortions are highly affected by aliasing. Thus in advance to the distortion an internal Fixed Zoom copy is made by bicubic interpolation. Depending on the size of the affected area we use Fixed Zoom = 2...16. If the area is very large then no copy is used and the markers on the screen appear red . The distortion is then applied in the copy and shown in original size on the screen. Any distortion is fading to the environment at the boundary of the affected area.

The reference points are called

- L Pullpoint or Lightpoint
- V Fixpoint or Viewpoint

#### 5.3.1 Shift Pull Mode

A vector field is defined which generates fading linear shifts in the interior of the shift area. A short visible vector shows the shift of the center of the ellipse to the focus.

Load	ZEBRA
Load	E:\Covi_525.bmp
F1	Tag Image
Select	Image Processing / Distortion / Shift Pull Mode
	Apply the distortion several times, using Undo.

Make a sketch of the scenery, draw the vector field and describe the process.



#### 5.3.2 Other Distortions

- Load E:\Covi\_530.bmp
- F1 Tag Image
- Select Image Processing / Distortion /

The next experiments can be performed without any practical use, just to show the features.

Shift Push Mode	Like Shift Pull Mode	
Tear Distortion	Sharp Shift	1
Angle	Complete Rotation, reference horizontal	
Half Plane Angle	Half plane rotation, references	
	0°/90°/180°/270° for sectors (example 0°)	
Positive Magnifier	Convex lupe	
Negative Magnifier	Concave lupe	
Out of Plane Rotation	Can generate sometimes the effect of a rot	ts



Out of Plane Rotation Can generate sometimes the effect of a rotation out of the plane

#### F3 Reload Image

Try to change to expression of the face from 'happy,friendly' to 'sceptical, indifferent'. Make a sketch which shows the fundamental distortions (but not in this book).

# Image Processing: Dithering, Compression and Colors

#### 6.1 Dithering

Ordered Dither is used for offset and laser printing. Raster cells with fixed width in Lpi distance are filled with dots in dpi distance. The dots form a coherent spot. This for each channel CMYK.

Error Diffusion is used for inkjets. We don't have raster cells, the ink drops are arranged in a way that the appearance of the image is simulated.

For Ordered Dither we need 1.5 to 2 pixels per raster cell, theoretically exactly one. A printer with 106 Lpi and 1200 dpi has  $n=(1200/106)^2+1 = 129$  levels per channel, including white. For the printed width 5 inch we need  $(1.5...2) \cdot 5 \cdot 106 = 795 \dots 1060$  pixels in this direction.

For offset printing we need 300 pixels per inch on the paper.

For inkjets we can assume a fictitious raster cell Lpi = dpi /10 . For 5 inch on the paper we need  $(1.5...2) \cdot 5 \cdot 72 = 540 \dots 720$  pixels in this direction.

#### 6.1.1 Ordered Dithering

Load	ZEBRA
Load	E:\Covi_540.bmp
Select	Image Processing / Halftone / Raster Halftone
Select	Width 8
ENT	Execute

The image is converted to grayscale and rastered.



The result (right) can be reproduced from this PDF only by a high resolution printer

#### 6.1.2 Error Diffusion

A printer has normally only four colors CMYK. We can simulate the dithering by using only three colors RGB - noRed / fullRed, noGreen / fullGreen, noBlue / FullBlue.

We can draw a Red pixel if the accumulated error is above half Red and keep the difference in mind. The same for Green and Blue.

Hilbert Peano uses a pseudo random path for walking through the image (refer to Fig. 6.6).

Floyd-Steinberg distributes the error to next neighbours (right in the same row and below and right in the next row).

The situation becomes more favourable if the printer can produce n=3 or more color levels or drop sizes, but this number n will be always small because of the inherent inaccuracies.

One of the levels is 'nothing', white paper. n=2 levels means 'nothing' or full color. Full color means one standard drop for inkjets.

Load ZEBRA Load E:\Covi\_400.bmp (Market) F1 Tag Image Select Image Processing / Halftone / Hilbert Dithering Try out several cases of color level.

How many different color levels n are necessary to achieve a satisfying result ?

F3 Reload image Select Image Processing / Halftone / Floyd-Steinberg Try out several cases of color levels.

How does Floyd-Steinberg distribute the errors ?

ESC Zebra Main

#### 6.2 Compression

#### 6.2.1 Indexed Color Compression

A True Color image BMP-32 or BMP-24, 4 byte per Pixel PRGB with 3 relevant bytes RGB, shall be converted to Indexed Color BMP-8 with 1 byte per pixel. Runlength Encoding is additionally applied, if the RLE code is shorter than the BMP-8 code. In other file formats the fourth byte P is called Alpha Channel A and used for transparency.

Explain Runlength Encoding.

Why can a BMP-RLE file be larger than a BMP-8 file ?

Indexed Color is still an important data format. Each pixel is described by one byte	which refers to a color
table with up to 256 triples R.G. and B.	
Which important graphics format for Web applications uses Indexed Color?	
This format uses the so-called LZW or ZIP compression.	
Explain the basic idea of LZW.	
•	

How many colors are available using True Color ?	
How many colors are possible in one Image 1280 x 1024, using True Color?	
How many colors are available using Indexed Color ?	
Which compression ratio, based on BMP-24, is achieved at least ?	

ZEBRA
E:\Covi_400.bmp (Market)
Image Processing / Icons+Compression
Indexed Icon 256 Colors / Fullscreen
Execute

Compare the sizes of the original file and the new file.

Describe the quality.

The image top right shows the available 256 colors, the palette, ordered by increasing lightness.

ESC Zebra Main Load E:\Covi\_600.bmp Select Image Processing / Icons+Compression Select Indexed Icon 256 Colors/Fullscreen ENT Execute

Compare the sizes of the original file and the new file.

Describe the quality (some ink printers print like this) . How is this effect called ?



ESC Zebra Main

#### 6.2.2 JPEG-Compression

JPEG divides the image into small blocks. Make a sketch of the block sizes. Explain 'subsampling'.

Split into grayscale Y (luminance) and residual colors Cb, Cr by approximate factors of the YCbCr-Matrix.

Y	=	R	G	В
Cb	=	R	G	В
Cr	=	R	G	В

Describe the basic functions for the Discrete Cosine Transform DCT by some sketches.

Describe the Quantization.

Describe ZigZag encoding.

Describe Runlength encoding and Huffman encoding

Describe the reverse process for decoding JPEG files

Which tables must be included in the file (DCT, YCbCr-coefficients, Quantization, ZigZag, Huffman)?

Load	ZEBRA
Load	E:\Covi_400.bmp (Market)
F1 Select	Tag Image
Select	Fullscreen / Low Quality
ENT	Execute

Describe the quality and the compression rate.

Select Undo

Select	Fullscreen / Medium Quality
ENT	Execute

Describe the quality and the compression rate.

Select Undo

SelectFullscreen / High QualityENTExecute

Describe the quality and the compression rate.

ESC Zebra Main

Load E:\Covi\_600.bmp (Lips) Select Fullscreen / Medium Quality ENT Execute

Describe the quality and the compression rate.

Why is the compression rate very high?

#### 6.3 Colors

#### 6.3.1 Application of Gradation Functions

Photoshop and ZEBRA use Gradation functions. In Photoshop they are called Curves.

A Gradation function G describes the relation NewColor = G (OldColor). These functions can be applied to RGB simultaneously or to each color individually.

Photoshop modifies the functions by mouse, whereas ZEBRA defines basic functions, which are mixed by key inputs, thus reversable:

Linear Gradation	0. Order Gradation
Nonlinear Gradation	1. Order Gradation
Nonlinear Gradation	2. Order Gradation

Moves endpoints of straight line left and right Makes a banana like distortion (half sine) Makes an S-like distortion. (full sine)

Draw examples for the basic functions for Gradation.



Which effects are expected for these examples ?

Load ZEBRA Load E:\Covi\_610.bmp

This digital image has a strong yellow tint. Apply White Balance.

Select	Image Processing / Color
	Move Mouse to background
Select	Linear White Balance
	RGB values are measured in a small test area.
	Adjust RGB to middle value, e.g. 235
ENT	Execute



Explain White Balance.

ESC	ZEBRA Main	
Load Select	E:\Covi_520.bmp (Face) Image Processing / Color Apply Linear Gradation	
Interpret the histogram (in Photoshop Levels and Histogram as well)		
Select	Undo Apply Nonlinear Gradation	

Which shape of the curves increases the contrast?

Select Undo Select HLS +Contrast Apply Contrast

This is the application of an S-like curve to the L-channel in HLS including a Gamma correction. Furtheron the very dark parts of the image are not made darker. In Photoshop it can be done in the Lchannel in the CIELab color space (Lab). Why is this method preferable to direct manipulations in RGB ?

#### **Exercise No.7**

#### **Computer Graphics**

# 7.1 Wireframes, Visibility, Rendering, Shadows

Load ZOTOP This is an artificial example for didactical purposes. ENT Run the whole cycle once. Select Quit



#### 7.1.1 Wireframes

Load ZOTOP

Explain the Wireframe Model

The scene consists of objects. Which objects can be distinguished ?

Objects consist of elements. Which geometrical elements were used ?

An element can consist of subelements. Which subelements for a cylinder ?

A pyramid is an element. A cube is a special case of a pyramid. Draw a general pyramid and some special versions.

A double elliptic cone is an element. A normal cone is a special case of a general cone. Draw a general cone and some special versions.

In which coordinates is an element defined ? How is it transformed into the Object Space ? Draw an example for a cube. Wires can have fixed colors or rendered colors. They can be applied without or with visibility check. Which style is used here ?

#### 7.1.2 Shadow Preparation

ENT Light Camera

What is the purpose of viewing from the Light source to the object ?

How should we choose the Light Camera Viewpoint and the Zoom?

#### 7.1.3 Rendering

#### ENT Camera

Elements and Subelements are subdivided into quadriliterals. Each quadriliteral consists od two triangles.

Which information for each triangle corner in 3D is required for the mapping to 2D and how is the transformation done mathematically?

Which information is necessary for each triangle corner in 3D for the calculation of colors and how is it done? The method is called Gouraud shading.

Which information is available in the Raster Image for each projected triangle corner ?

How is the triangle in 2D filled ?

How is the visibility checked ? Make a sketch for the Z-buffer algorithm.

#### 7.1.4 Shadow

ENT Shadow

Up to now two depth-Buffers are filled: the L-Buffer and the Z-Buffer. How can we decide whether a pixel belongs to the shadowed area ? Make a sketch.

Why is this method highly affected by Aliasing ?

Which color should be assigned to shadow areas ?

Why don't we get an umbra (Kernschatten) and a penumbra (Halbschatten) ?

How could we produce shadows from multiple light sources ?

Which perceptual feature may cause the appearance of stripes in multiple shadows ?

#### 7.1.5 Soft Shadows

#### ENT Soft Shadow

This a fully automatical application of Image Processing. Elements are separated (segmented). Shadow areas are marked by a shadow byte. A shadow contour point is softened, if it belongs to the same Element. The contour of the intersection of the cones is not softened.

Draw a cube on a plane with shadows and show which boundaries are soft and which not.

#### 7.1.6 Anti Aliasing

ENT Anti Aliasing Explain the process.

#### Q Quit

#### 7.2 Light Models, Reflexion, Texture Mapping

#### 7.2.1 Light Models and Reflexion

Load ZEFIR Select Object / Lambert Select Phong

Reflexion is a feature of the object. Compare Lambert and Phong. Make sketch.

#### 7.2.2 Texture Mapping

Select Texture / Image for Texture

Load E:\Covi\_710.bmp

Select Texture / Adjust Geometry

Try several adjustments in the Parameter Plane and in the Texture Plane until the face appears undistorted on the face of the cube. Make a drawing of the Parameter Plane and the Texture Plane.



SelectObject / Type / SphereSelectTexture / Adjust Geometry

Try several adjustments until the whole face is visible on sphere. Which coordinates are used for the sphere and how are they related to the Parameter Plane ? Make a sketch.

#### 7.2.3 Texture Mix

Select Default / Object + Texture Select Texture / Texture Mix Select Unmixed Map Relative Mix Highlight Mix

For a paper picture on a can (Konservenbüchse) we would use:

Directly printed on metal we would use:

Which interpolation method should be used for the texture mapping ?

Explain 'Bump Mapping', using a sketch.

Old links:

http://www.fho-emden.de/~hoffmann/

http://www.fho-emden.de/~hoffmann/filename.pdf

Please use since February 2013 New links: http://docs-hoffmann.de/ http://docs-hoffmann.de/filename.pdf