TTE-5516 Machine Vision and Optical Measurements, Fall 2010 Exam February 21st 2011

Use of literature is not allowed but use of calculator is allowed. Exam papers must be returned. Maximum points for the exam are 30 and you need 15 to pass the exam.

1. Explain (write and/or draw) the following machine vision related terms, max. about 5 lines per item (1 point per item, max 5 points)
    a. Spatial resolution
    b. Histogram of an image
    c. Camera image white balance adjustment
    d. Diffuse front side illumination
    e. Line Fit (to an edge) tool operating principle

2. We have targets of varying colors, shapes, and sizes located on a 600x400 mm area. The targets are thin, flat, and not transparent. They never are on top of each other and they never touch each other. The idea is that a machine vision system locates and a robot picks targets having a certain surface area independent of their color. The background and the illumination can be chosen freely. Answer and **give reasons** for the following items:
    a. Choose a camera from the attached list so that you achieve a spatial resolution of about 0.5 mm/pix. What will be the exact spatial resolution with the camera you chose? (1 point)
    b. What kind of measurement resolution you can expect to achieve with the selected camera? (1 point)
    c. Select the imaging geometry and distance for the selected camera when we want to use a 16 mm focal length lens. (2 p)
    d. What kind of illumination you would use if you can freely choose? Why? (2 p)
    e. What kind of machine vision tool you would use to select and to locate the targets? Shortly explain the operating principle and the main parameters of the selected tool. (2 p)
    f. Shortly describe how you would do system (camera + robot) calibration. What things you should consider during calibration? (2 p)

Some (maybe) useful equations

$$m = \frac{h''}{h} = \frac{s''}{s} \qquad \frac{1}{f} = \frac{1}{s} + \frac{1}{s''} \qquad \frac{f}{z} = \frac{r'}{r} \qquad \frac{x'}{x} = \frac{y'}{y} = \frac{r'}{r} \qquad f = h_d \frac{D}{h_{FOV}} \qquad f = w_d \frac{D}{w_{FOV}}$$

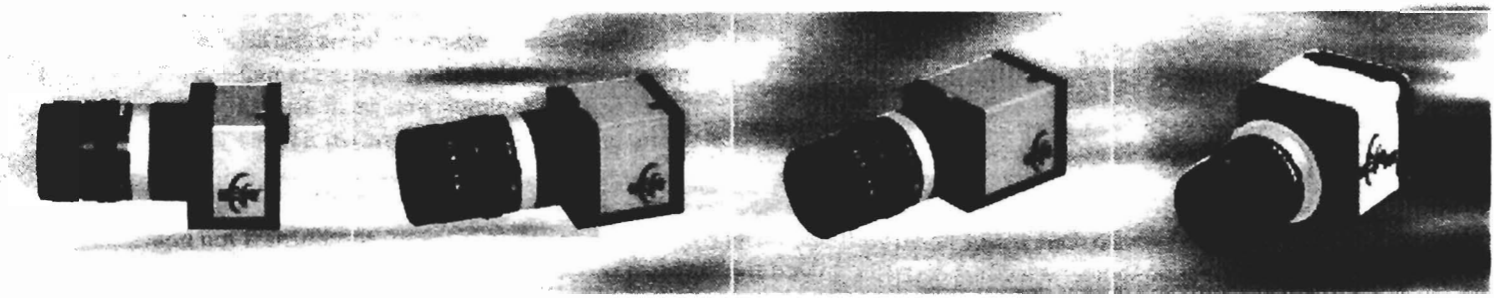
$$M_{ij} = \sum_{x=1}^{N} \sum_{y=1}^{M} x^i y^j f(x,y) \qquad X = \frac{M_{10}}{M_{00}} \qquad Y = \frac{M_{01}}{M_{00}}$$

(Sum of maximum points for problems 3 and 4 is 15)

3. The evaluation of uncertainty for measurement needs traceability and list of parameters of the uncertainty. Make a list of uncertainty parameters affecting in the Assignment no 5. "Straightness measurement using CCD camera and optical laser reference line"

4. Tell about the typical technical features of the CCD-Camera based Co-ordinate measuring machines and measurements. What are the most typical features for the camera, light sources and software? Do not tell about Machine Vision solutions!

All uEye®-Models



Sensor Technology	CMOS	CMOS	CMOS	CMOS	CMOS	CMOS
Model (Color)	UI-1220-C	UI-1410-C	-	UI-1450-C	UI-1460-C	UI-1480-C
Model (Mono)	UI-1220-M	UI-1410-M	UI-1540-M	-	-	-
Resolution (h x v)	752 x 480	640 x 480	1280 x 1024	1600 x 1200	2048 x 1536	2560 x 1920
Resolution Category/Pixel Class	WVGA	VGA	SXGA/1.3 MP	UXGA/2 MP	SUXGA/3.3 MP	QSXGA/5 MP
Sensor Size	1/3"	1/3"	1/2"	1/2"	1/2"	1/2"
Shutter	Global	Rolling	Rolling	Rolling	Rolling	Rolling/Global Start
Max. fps in Freerun Mode at full resolution	87 fps	35 fps	25 fps	18 fps	11 fps	6 fps
Max. fps in SW Trigger Mode at 1 ms exposure	78 fps	17 fps	23 fps	16 fps	10 fps	5 fps
Exposure Time in Freerun Mode	80 µs - 5,5 s	56 µs - 630 ms	35 µs - 980 ms	45 µs - 1,25 s	57 µs - 1,75 s	81 µs - 680 ms
Exposure Time in Trigger Mode	80 µs - 5,5 s	56 µs - 630 ms	35 µs - 980 ms	45 µs - 1,25 s	57 µs - 750 ms	81 µs - 680 ms
AOI Modes	H² + V²	H + V²	H² + V²	H² + V²	H² + V²	H² + V²
AOI with 320 x 240 Pixels (CIF)	215 fps	68 fps	232 fps	242 fps	220 fps	126 fps
Subsampling Modes	-	H + V²	H² + V² (Color)	H² + V²	H² + V²	H² + V²
Subsampling Factors	-	x2	x2, x4	x2, x4	x2, x4	x2, x4
Resolution, fps	-	320 x 240, 68 fps	640 x 512, 79 fps 320 x 256, 219 fps	800 x 600, 60 fps 400 x 300, 177 fps	1024 x 768, 37 fps 512 x 384, 113 fps	1280 x 960, 19 fps 640 x 480, 53 fps
Binning Modi	H + V² (Mono)	-	-	-	H² + V²	H² + V²
Binning Methode	H + V: Average	-	-	-	H: Sum V: Average	H: Sum V: Average
Binning Factors	x2, x4	-	-	-	x2, x4	x2, x4
Resolution, fps	368 x 240, 162 fps 176 x 120, 286 fps	- -	- -	- -	1024 x 768, 30 fps 512 x 384, 79 fps	1280 x 960, 15 fps 640 x 480, 23 fps
Mono: Maximum Gain	4x	25,2x	12x	-	-	-
Color: Maximum Gain RGB/Master	5x (SW)/4x	5x/5x	-	12x/-	7,25x/12x	6,5x/12x
Additional Gain Boost with Factor	1,6x	2x	1,5x	1,4x	2x	1,6x
Sensor Model	MT9V032	KAC-9618/28	MT9M001	MT9D001	MT9T001	MT9P031
Pixel Clock	5 - 40 MHz	5 - 14 MHz	5 - 43 MHz	5 - 43 MHz	5 - 43 MHz	5 - 43 MHz
Pixel Pitch in µm	6,0	7,5	5,2	4,2	3,2	2,2
Full Well Capacity	30.000 e-		40.000 e-	30.000 e-	20.000 e-	15.000 e-
Optical Size	4,51 x 2,88 mm	4,80 x 3,60 mm	6,66 x 5,32 mm	6,72 x 5,04 mm	6,55 x 4,92 mm	5,63 x 4,22 mm
Aspect Ratio	14:9	4:3	5:4	4:3	4:3	4:3
Exact Real Diagonal	5,4 mm, 1/3,0"	6,0 mm, 1/2,7"	8,5 mm, 1/1,9"	8,4 mm, 1/1,9"	8,2 mm, 1/2,0"	7,0 mm, 1/2,3"
Current Consumption at 5 V	100 - 130 mA	80 - 110 mA	130 - 170 mA	100 - 140 mA	90 - 130 mA	90 - 130 mA
Regulations	CE class A, CE class B, FCC (depending on model)					

² = Use increases frame rate