Information page for written examinations at Linköping University

Examination date	2016-08-19
Room (1)	TER2
Time	8-12
Course code	TSBB09
Exam code	TEN2
Course name **Exam name**	Images Sensors (Bildsensorer) Written examination (Skriftlig tentamen)
Department	ISY
Number of questions in the examination	24
Teacher responsible/contact person during the exam time	Klas Nordberg
Contact number during the exam time	013-281634, 0739-037628
Visit to the examination room approximately	around 10 am
Name and contact details to the course administrator (name + phone nr + mail)	
Equipment permitted	Calculator, pen and paper
Other important information	
Number of exams in the bag	

Guide

The written examination consists of 3 parts, one part for each of the three course aims in the curriculum.

- Part I: standard image sensors, including IR
- Part II: geometry and multiple views
- Part III: non-standard image sensors

Each part consists of 6 exercises where the student should demonstrate ability to explain concepts, phenomena, etc (type A exercises), and 2 additional exercises that test a deeper understanding of various topics in the course, for example, in terms of simpler calculations (type B exercises).

Type A exercises give at most 1 point each. Type B exercises give at most 2 points each.

To pass with grade 3: At least one type B exercise passed (i.e., with 2 points) for the whole examination AND at least a total of 4 points each in each of the three parts.

To pass with grade 4: At least three type B exercises passed for the whole examination AND at least a total of 6 points each in each of the three parts.

To pass with grade 5: At least five type B exercises passed for the whole examination AND at least a total of 8 points each in each of the three parts.

The answers to the A-exercises should be given in the blank spaces of this examination thesis, below the questions. If an A-exercise requires two pieces of information, indicated by an "AND", both should be given to get 1p. Otherwise 0p is given.

The answers to the B-exercises should be given on blank paper sheets, with no more than one exercise per sheet, that will be appended to the thesis by the student.

Write your AID code at the top of the pages in this examination thesis and any sheet appended to the examination thesis. Appended sheets must also have the course code and date written on them and be numbered.

Good luck!
Klas Nordberg and Maria Magnusson

PART I: STANDARD & IR IMAGE SENSORS

Exercise 1 (A, 1p) Light from two separate monochromatic sources with different wavelengths, $\lambda_1 < \lambda_2$, are measured by a light sensor. It senses the same energy per time and area unit for both sources. Does this mean that the number of detected photons per time and area unit from the first source, n_1, is the same as from the second source, n_2, or is it the case that $n_1 < n_2$ or $n_1 > n_2$? Motivate your answer.

Exercise 2 (A, 1p) Describe the distinct difference between an image produced by a camera using a *global shutter* versus a *rolling shutter*.

Exercise 3 (A, 1p) Explain the concept *depth of field* for a lens based camera.

Exercise 4 (A, 1p) Describe the concept of the *virtual image plane* of a pin-hole camera, and how it differs from the normal image plane.

AID code:

Exercise 5 (A, 1p) A digital camera is subject to *shot-noise* (pixel noise). Why does this noise occur?

Exercise 6 (A, 1p) The infra-red wave-length range is usually divided into a number of intervals, one of which is referred to as *near IR* (or NIR). Which wave-length band do you find immediately below the NIR interval, i.e., that have shorter wave-lengths than NIR?

Exercise 7 (B, 2p) Explain the so-called *transport problem* in an image sensor, and describe in general how it is solved in the case of a CCD-sensor and a CMOS-sensor. Explain the qualitative differences in the image measurement process that the two solutions produce.

WRITE YOUR ANSWER ON A SEPARATE SHEET

Exercise 8 (B, 2p) Describe the basic measurement cycle of the *photo diode* as it is used in a digital camera. Describe which electrical quantity, proportional to the incident light, it produces and how.

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PART II: GEOMETRY AND MULTIPLE VIEWS

Exercise 9 (A, 1p) In order to stitch a set of smaller images to larger panorama image, it is important that the initial set of images are taken by rotating the camera around its center. Explain way.

Exercise 10 (A, 1p) How many constraints on the fundamental matrix, $\mathbf{F}$, are provided by one pair of corresponding image points?

Exercise 11 (A, 1p) The intrinsic camera parameters are represented as

$$\mathbf{A} = \begin{pmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{pmatrix}.$$

Why can we often assume that $\gamma \approx 0$?

AID code:

Exercise 12 (A, 1p) Why are the image panoramas that are created in the computer exercise combined in a spherical coordinate system, rather than an ordinary Cartesian coordinate system?

Exercise 13 (A, 1p) Assume that $\mathbf{x} = (X, Y, Z, 1)^T$ are the homogeneous coordinates of a point in the world coordinate system and that $\mathbf{y} = (U, V, W)^T$ are the homogeneous coordinates of a point in a normalized camera coordinate system. The relation between the two homogenous coordinates are

$$\mathbf{y} \sim [\mathbf{R}\,\mathbf{t}]\,\mathbf{x},$$

Suppose that the camera is translated a distance $(10, 20, 30)$ in relation to the world origin and rotated an angle $0°$ around the Y-axis. Give the $[\mathbf{R}\,\mathbf{t}]$ matrix!

Exercise 14 (A, 1p) Reconstruction of a 3D point based on the positions of its projection in a pair of stereo images can be done using a linear method. How can you derive *linear equations* in the unknown 3D point $\mathbf{x}$ based on the usual camera projection equations:

$$\mathbf{y}_1 \sim \mathbf{C}_1\,\mathbf{x} \qquad \text{and} \qquad \mathbf{y}_2 \sim \mathbf{C}_2\,\mathbf{x}$$

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Exercise 15 (B, 2p) In a pair of stereo images, a point in one image corresponds to a line in the other image. Motive why this is so.

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Exercise 16 (B, 2p) Zhang's method for camera calibration is based on the expression

$$\lambda \, \mathbf{A} \, [\, \mathbf{r}_1 \; \mathbf{r}_2 \; \mathbf{t} \,] = [\, \mathbf{h}_1 \; \mathbf{h}_2 \; \mathbf{h}_3 \,]$$

where $\lambda \neq 0$ is a scaling parameter which implies that the left hand side is proportional to the right hand side. Describe the remaining parameters in the above equation and explain how they allow you to formulate two constraints that are useful for camera calibration.

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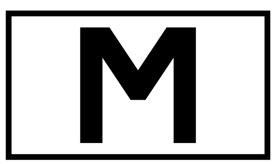
PART III: NON-STANDARD IMAGE SENSORS

Exercise 17 (A, 1p) A satellite produces images of the earth using a line camera, thereby forming a push-broom camera. What is the advantage of using a line camera in this case?

Exercise 18 (A, 1p) A flat surface has a printed pattern, shown below. It is scanned with a range camera based on sheet-of-light and triangulation. Although the surface is flat, the resulting range image contains minor deviations from a flat surface. Explain why and describe where the range deviations occur.



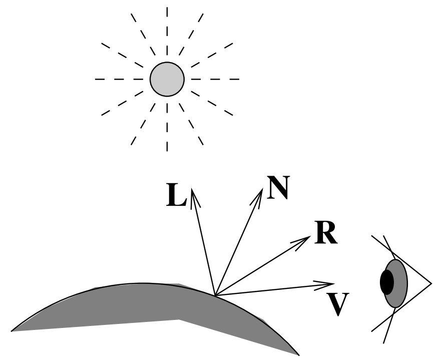
Exercise 19 (A, 1p) Modern medical CT-scanners produce high quality 3D volumes. It is common to use a helix-shaped source path. Describe how such a source path is obtained in terms of how the X-ray source, the detector and the patient move.

AID code:

Exercise 20 (A, 1p) The intensity I at a point on an object can be written

$$I = I_a \cdot k_d + I_l \cdot k_d \cdot \cos\varphi + I_l \cdot k_s \cdot (\cos\theta)^n.$$

State mathematical expressions for the angles φ and θ in terms of the vectors $\mathbf{L}, \mathbf{N}, \mathbf{R}$ and $\mathbf{V}$, defined in the figure below.

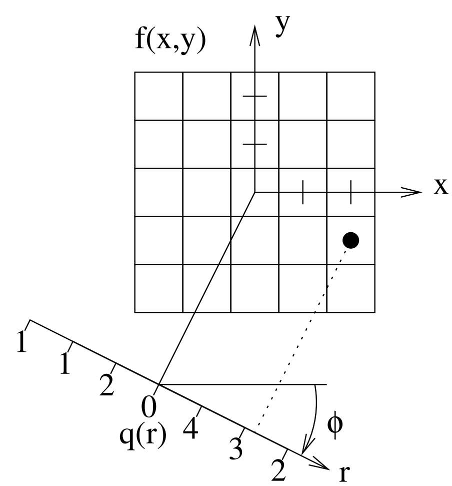


Exercise 21 (A, 1p) An active range camera, e.g. SICK-IVP's laser sheet-of-light or MICROSOFT's KINECT, can measure the shape of many types of objects. An object with a specular surface might cause problems, however. Why?

Exercise 22 (A, 1p) How can occlusion in general be detected in the sensor image for a sheet-of-light range camera?

AID code:

Exercise 23 (B, 2p) See the figure below that illustrates backprojection of the filtered projection $q(r)$ over the image $f(x, y)$. Which value is backprojected at the position $(x, y) = (2, -1)$? Use linear interpolation. Let the distance between projection values as well as between pixels in the image be the same. The projection angle is $\phi = -26.565°$.



WRITE YOUR ANSWER ON A SEPARATE SHEET

Exercise 24 (B, 2p) A 3D volume of data is generated from a 3D tomography device. Describe the computational steps that are necessary in order to compute the required information to produce a 2D image based on surface shading using the Blinn-Phong model.

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