Information page for written examinations at Linköping University

Examination date	2015-04-07
Room (1)	TER2
Time	14-18
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 3 pm and 5 pm
Name and contact details to the course administrator (name + phone nr + mail)	
Equipment permitted	Calculator
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

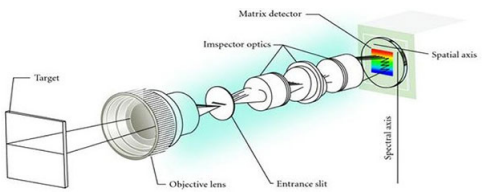
PART I: STANDARD & IR IMAGE SENSORS

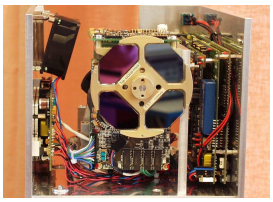
Exercise 1 (A, 1p) When light passes through the camera aperture, the wave nature of the light causes *diffraction*. Describe how this diffraction affects image formation process in a camera.

Exercise 2 (A, 1p) How does *vignetting* manifest itself in an image?

Exercise 3 (A, 1p) Explain the basic principles of a *push-broom camera*.

Exercise 4 (A, 1p) Bayer images which have been converted to RGB images, sometimes exhibit artifacts in the vicinity of sharp edges. Explain why these artifacts appear.





Exercise 5 (A, 1p) A multi-spectral image can be implemented by a prism that splits the incoming light into spectral bands, which are detected by different rows of a 2D image sensor (left image). An alternative approach is to have a rotating filter wheel in front of the sensor (right image). Describe the characteristic properties of BOTH approaches, that would make you choose one instead of the other?

Exercise 6 (A, 1p) High quality cameras in the infra-red range are often equipped with a cooling system. Why?

Exercise 7 (B, 2p) You are involved in a team that develops a new version of a digital camera. Since the sensor area is not allowed to increase, some of your colleagues suggest that the new design could increase the number of pixels in the sensor by shrinking their size. You, on the other hand, argue that this will increase the noise in the image. How do you motivate this statement? Assume that only the pixel size is reduced, everything else is the same.

WRITE YOUR ANSWER ON A SEPARATE SHEET

Exercise 8 (B, 2p) There is a physical law that says: the incoming light energy per area unit decreases as the inverse of the square of the distance to the light source. Intuitively, this may lead to the conclusion that we perceive objects as darker the further away they are. This is not the case in reality. Explain why.

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PART II: GEOMETRY AND MULTIPLE VIEWS

Exercise 9 (A, 1p) Why do we want to rectify stereo images?

Exercise 10 (A, 1p) In order to build a panorama image from images taken in different directions it may be advantageous to first map the images to the surface of a sphere. Explain why.

Exercise 11 (A, 1p) The mid-point method for triangulation of 3D points cannot give a reliable result for a particular case that can occur in practice. Which case?

Exercise 12 (A, 1p) Why is it not a good idea to make a panorama mosaic image of images taken from different positions, i.e., where the camera center has moved between the shots?

Exercise 13 (A, 1p) Which one of the three statements below, about the epipolar constraint, is correct?

1. $\mathbf{y}_1$ and $\mathbf{y}_2$ are corresponding points if $\mathbf{y}_1^\top \mathbf{F}\, \mathbf{y}_2 = 0$.
2. $\mathbf{y}_1$ and $\mathbf{y}_2$ are corresponding points if and only if $\mathbf{y}_1^\top \mathbf{F}\, \mathbf{y}_2 = 0$.
3. $\mathbf{y}_1^\top \mathbf{F}\, \mathbf{y}_2 = 0$ if $\mathbf{y}_1$ and $\mathbf{y}_2$ are corresponding points.

Exercise 14 (A, 1p) The expression below describes the projection of a 3D point (X, Y, Z) to an image point (u, v). Describe which parameters in this expression are called *outer parameters* or *external parameters*, AND explain why?

$$s \begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \mathbf{A}[\mathbf{R}\,\mathbf{t}] \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix}$$

Exercise 15 (B, 2p) Describe the different steps in the 8-point algorithm for estimating the fundamental matrix $\mathbf{F}$ from a set of N corresponding image points with homogeneous coordinates $\{\mathbf{y}_{1,k}, \mathbf{y}_{2,k}\}, k = 1, \ldots, N$.

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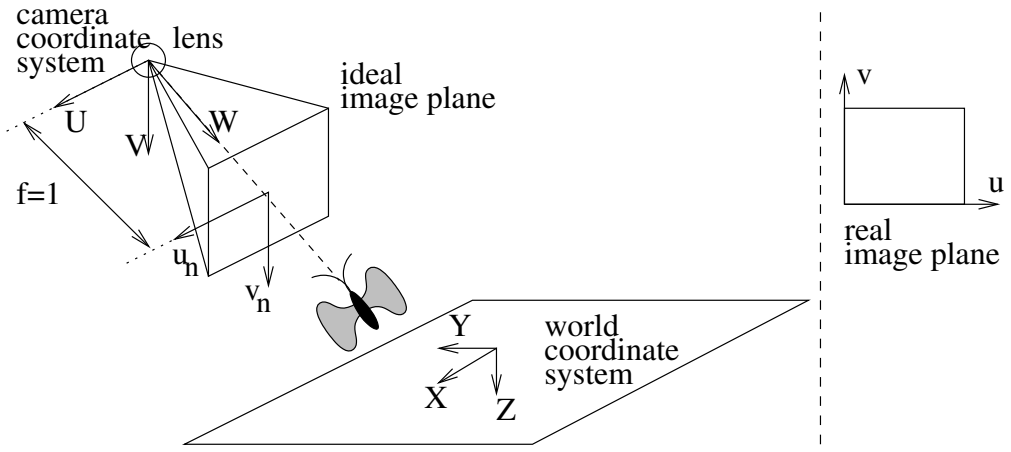
Exercise 16 (B, 2p) The figure below shows the 3D world, a camera, a normalized image plane (with focal length $f = 1$) and a real image plane in the camera. These are the connections between the coordinate systems, as well as the current $\mathbf{A}$-matrix:

$$s \begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \mathbf{A}[\mathbf{R}\,\mathbf{t}] \begin{pmatrix} X \\ Y \\ Z \\ 1 \end{pmatrix}, \qquad \begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = \mathbf{A} \begin{pmatrix} u_n \\ v_n \\ 1 \end{pmatrix}, \qquad \mathbf{A} = \begin{pmatrix} 500 & 0 & 500 \\ 0 & 450 & 400 \\ 0 & 0 & 1 \end{pmatrix}.$$



The camera can rotate in two angular directions θ_u and θ_v (horizontally and vertically). The image center is located at the coordinate $(u, v) = (500, 400)$. The camera should follow an object in the scene, here a butterfly. At some point in time the butterfly is located at image coordinate $(u, v) = (275, 325)$. How much should the camera rotate, in terms of the angles θ_u and θ_v, to bring the butterfly to the center of the image?

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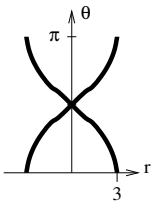
PART III: NON-STANDARD IMAGE SENSORS

Exercise 17 (A, 1p) Explain the concept of a *catadioptic* camera.

Exercise 18 (A, 1p) Consider the sinogram given below. Draw the object that gives this sinogram. The axes must be graded.



Exercise 19 (A, 1p) One approach to active range cameras is *Time of flight*, which can be implemented based on two different principles. One principle is *Amplitude modulated light and phase shift measurement*. Describe the second principle.

Exercise 20 (A, 1p) A second approach for active range cameras is *Active light and triangulation*. The active light can be a random dot-pattern as in KINECT version 1. How are corresponding points in the image and in the pattern detected?

Exercise 21 (A, 1p) A range camera is based on a triangulation and a sheet-of-light laser. Three types of objects are measured: a white matte object, a shiny metal object, and a dark-grey matte object. Which of the objects is easy to measure AND which is difficult to measure? Justify your answer.

Exercise 22 (A, 1p) The following equation is used both in computed tomography (CT) and 3D-visualization. **In the case of 3D-visualization:** Explain the variables I, I_0, L, and μ AND explain which physical phenomena the equation is able to model.

$$I = I_0 \exp\left(-\int_L \mu(x,y)dl\right)$$

Exercise 23 (B, 2p) The program below calculates a normal projection image along the y-direction, `P(x,z)`. Modify the program so that it calculates both a MIP image, `M(x,z)`, and a depth-coded image, `D(x,z)`. Use the threshold $T = 100$.

```
for z=-127 to 128
      for x=-127 to 128
            P(x,z):=0;
            y:=-127;
            do
                  P(x,z):=P(x,z)+f(x,y,z);
                  y:=y+1;
            while (y<129)
      end;
end;
```

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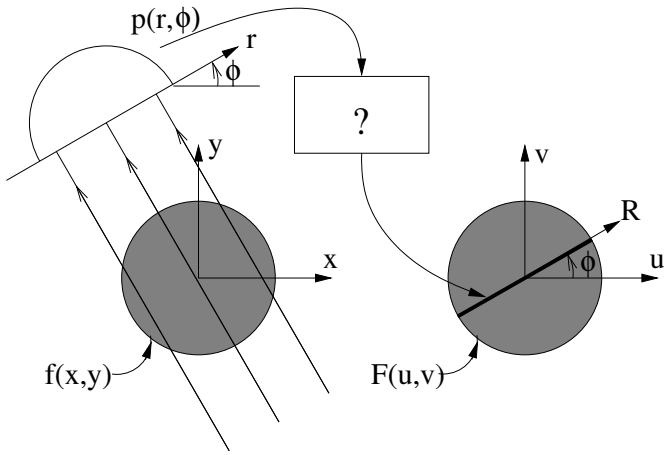
Exercise 24 (B, 2p) The figure below illustrates a theorem. Describe this theorem! Refer to the figure and the notations $f(x,y)$, $F(u,v)$, $p(r,\phi)$ and ϕ in your story. Also mention what is done in the box with the question mark!



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