T-61.5070 Computer Vision

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Answers can be given in English, Finnish or Swedish.

1. Explain briefly, with 20–40 words or a mathematical definition, the following concepts or abbreviations: 6p.

(i) relaxation in computer vision
(ii) invariance of features
(iii) Laws' texture energy measures
(iv) generalized Hough transform
(v) point distribution model
(vi) optical flow

2. (i) Explain the role of 3D models in computer vision systems. (ii) Explain when a 3D representation is *complete* and when it is *unique*. (iii) Give examples of different types of 3D models and other ways of presenting 3D information. Discuss their pros and cons. (iv) Explain the Line labeling algorithm, the 3D model used in it, its *a priori* assumptions and limitations. 6p.

3. Let us assume that a two-eyed creature's eyes are 100 mm apart and the focal length of the eyes is 50 mm. The midpoints of the image planes are symmetrically located on both sides of the origin along the x coordinate axis. The eyes are parallelly oriented in the direction of positive z axis. (i) Draw a figure illustrating the stereo geometry in the described system. (ii) Calculate the projections of the points in the xz plane in the coordinate systems of both eyes. (iii) Plot the difference of the x_l and x_r coordinates as a function of the distance z. (iv) What is the range where the described eye pair is usable for distance measurement, when the resolution of the eyes is 50 lines/mm? (v) What is the resolution of distance information when the distance is 10 meters? (vi) What size of an object at the distance of 100 meters is seen as the size of one pixel in the eye's image plane? 6p.

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4. Image segmentation by using the single-pass split-and-merge algorithm is studied. (i) Draw images of all the 2×2-sized basic patterns for image splitting. (ii) Perform the single-pass segmentation to the image below by using the following rule: the brightnesses of two 4-neighbor pixels belonging to a same region can maximally differ by one. Explain all the steps in the segmentation. (iii) In what cases can the simple rule of the above task lead to a non-unique interpretation? (iv) Could the same segmentation result have been obtained with histogram thresholding? (v) What are the general problems involved in this segmentation method? (vi) What other kinds of segmentation methods do exist? 6p.

$$\begin{array}{cccc} 1 & 2 & 7 & 7 \\ 1 & 4 & 5 & 7 \\ 5 & 3 & 4 & 6 \\ 5 & 5 & 6 & 6 \end{array}$$

5. The use of B-spline representation for curve description is studied. (i) Express the general function form with which the course of the B-spline curve $\mathbf{x}(s)$ is determined by control points $\mathbf{v}_i$ and base functions $B_i(s)$. (ii) Let the base functions of a third-degree B-spline be of the form:

$$\begin{aligned} C_0(t) &= \frac{t^3}{6} \\ C_1(t) &= \frac{-3t^3+3t^2+3t+1}{6} \\ C_2(t) &= \frac{3t^3-6t^2+4}{6} \\ C_3(t) &= \frac{-t^3+3t^2-3t+1}{6} \end{aligned} .$$

Sketch the shapes of the base functions. (iii) Show that the base functions sum up to one and are non-negative when $t \in [0,1]$. (iv) Show that the base functions are continuous in their start and end points and so are also their first and second derivatives. (v) Let the control points of a third-degree B-spline be $\mathbf{v}_1 = (1,1)$, $\mathbf{v}_2 = (3,4)$, $\mathbf{v}_3 = (4,2)$ and $\mathbf{v}_4 = (6,3)$. Calculate the coordinates of the start, middle and end points of the part of the spline curve determined by the given control points. Also, draw a picture and sketch the course of the spline. (vi) Enumerate advantageous characteristics of B-splines for curve description. 6p.