EXAM COMPUTER VISION, INMCV-08

April 8, 2013, 9:00-12:00 hrs

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During the exam you may use the lab manual, copies of sheets, **provided they do not contain any notes.**

Put your name on all pages which you hand in, and number them. Write the total number of pages you hand in on the first page. Write clearly and not with pencil or red pen. ***Always motivate your answers.*** *Good luck!*

Problem 1. (2 pt) Given a camera with unknown camera constant f, which images a parallelogram $ABCD$ via perspective projection on the plane $z = f$ (**ccc**-system). The sides AB and AD are at a known angle α, see Fig. 1. Furthermore, one corner of the parallelogram is known: $A = (0, 0, 3)$.

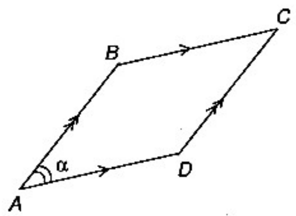


Figure 1: *Four line segments forming a parallelogram.*

The vanishing point of the parallel sides AB and DC is $(u_\infty, v_\infty) = (2, 1)$.
The vanishing point of the parallel sides AD and BC is $(u'_\infty, v'_\infty) = (-1, -2)$.

a. (1 pt) Compute the camera constant f as a function of α.

b. (1 pt) The equation for the plane V in which the parallelogram lies is given by

$$V: \quad Ax + By + Cz + D = 0. \tag{1}$$

Compute constants A, B, C, and D assuming the parallelogram is a rectangle, i.e. $\alpha = \pi/2$

Problem 2. (2.5 pt) Consider a surface centred at the origin with equation

$$z(x, y) = d - x^2 - y^4$$

The surface is Lambertian with constant albedo $\rho_S = 1$, and is illuminated by a light source at a very large distance, from a direction defined by the unit vector $\vec{s} = (a, b, c)^T$, with c negative. The camera is on the negative z-axis.

a. (1.0pt) Determine the image intensity $E(x, y)$ under orthographic projection ($u = x$,$v = y$).

b. (0.5pt) Suppose $\vec{s} = (1, 0, 0)^T$, i.e., the light source is in the direction of the positive x-axis. What is the observed light intensity $E(x, y)$ for $x < 0$?

c. (1.0pt) Given $E(x, y)$, can we reconstruct the surface function $z(x, y)$? If not: what is missing and what could we do to resolve the problem.

Problem 3. (2.5pt) Consider the three axioms for granulometries. A granulometry is a set of operators $\{\alpha_r\}$ with r from some totally ordered set Λ

$$\alpha_r(f) \leq f, \tag{2}$$

$$f \leq g \Rightarrow \alpha_r(f) \leq \alpha_r(g), \tag{3}$$

$$\alpha_r(\alpha_s(f)) = \alpha_{\max(r,s)}(f), \tag{4}$$

a. (0.5 pt) Show that for any granulometry, all α_r must be algebraic openings (*idempotent*, *anti-extensive* and *increasing*).

Now consider a set of marker images $\{g_r\}$, $r = 0, 1, \ldots, N$ such that $g_i \geq g_j$ for all $i \leq j$, and $f \geq g_i$ for all i. From this set of markers we can derive a set of operators $\{\alpha_r\}$, $r = 0, 1, \ldots, N$, with

$$\alpha_r(f) = \rho(f|g_r), \tag{5}$$

with ρ the reconstruction from a marker.

b. (1.0pt) Show that each α_r is an algebraic opening

c. (1.0pt) Show that the absorption property holds, i.e:

$$\alpha_s(\alpha_t(f)) = \alpha_{\max(s,t)}(f) \qquad \forall s, t \in \{0, 1, \ldots, N\}.$$

and that therefore $\{\alpha_r\}$ is a granulometry.

Problem 4. (2 pt) Consider the use of snakes to segment a simple grey-scale image given in Fig. 2(a). The aim is to find the contour of the dividing bacterium as shown in Fig. 2(b) (i.e., it need not be split into two parts).

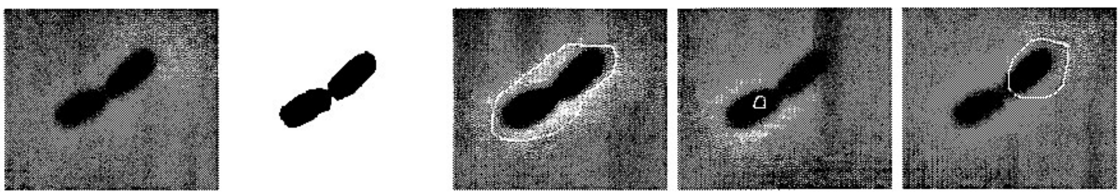
a. (1 pt) Which of the initializations in Fig. 2 is best for an expanding snake (i.e. with a force at right angles to the snake in the outward direction). Discuss why it works in the best case, and how and why it should fail in the others.

Let $\vec{v}(s)$ denote the location on the contour at arc length s from an arbitrarily chosen point on the snake.

$$E_{snake} = \int_0^1 [E_{int}(\vec{v}(s)) + E_{image}(\vec{v}(s)) + E_{con}(\vec{v}(s))]ds, \tag{6}$$

with E_{int} the *internal energy* of the contour due to bending or discontinuities, E_{image} the *image forces* derived from the image data, and E_{con} the *external constraints*.

b. (1 pt) Which term would need to be adapted to allow the snake to follow the sharp indentations (concave corners where the bacterium is splitting apart) in the contour of the shape in Fig. 2(b)? What approach could be used?



(a) (b) (c) (d) (e)

Figure 2: *Phase-contrast image of bacterium: (a) original image; (b) ideal object shape; (c), (d) and (e) initial position of snake superimposed on (a) in white.*