EXAM COMPUTER VISION, INMCV-08 (RESIT)

May 6, 2015, 18:30-21:30 hrs

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.*** *The total number of points to be earned is 9, one is added for free. Good luck!*

Problem 1. (2.0 pt) Consider a surface of the form

$$z = d + ax^2 + by^2$$

a. (1.0 pt) Assuming a homogeneous texture with texture constant ρ_0, determine the observed texture density $\Gamma(u, v)$ under parallel projection ($u = x, v = y$).

b. (0.5 pt) Assuming we observe the density $\Gamma(u, v)$ you derived, and you were able to derive the surface normal at each point. What extra assumption would you need to make to reconstruct the surface (z values) itself (up to a constant distance)?

c. (0.5pt) Neither shape from shading nor shape from texture derive surface normals unambiguously from a single image. Which of these two methods offers tighter constraints on the surface normal and why?

Problem 2. (2.5pt) In grey scale, a dilation of digital image f with flat structuring element S can be defined as

$$(f \oplus S)(x, y) = \max_{(x',y') \in B} (f(x - x', y - y')),$$

i.e. at each point the new output image value is the maximum within a surroundings of point (x, y) defined by set S. A nonlinear scale space can be implemented as a series of dilations with structuring elements of the form $t\,B$ with B a *disc* of radius 1 centred on the origin, where $t > 0$ is a scaling parameter:

$$\mathcal{S}^t\, I = I_+(x, y, t) = I \oplus t\,B \tag{1}$$

which is equivalent to solving the PDE:

$$\frac{\partial I_+(x, y, t)}{\partial t} = |\mathrm{grad}\, I_+(x, y, t)| \tag{2}$$

with $I_+(x, y, 0) = I(x, y)$ the original image. Note that the shape of the discs depends on the distance measure used (Manhattan, Euclidean, L_∞).

a. (0.5 pt) Argue that this nonlinear scale space is translation invariant (Hint: no involved math needed!)

b. (0.5pt) What shape of structuring element is needed, or alternatively, what metric is needed to ensure rotation invariance?

c. (1.0pt) Show that this scale space is causal in the sense of

$$\mathcal{S}^s \mathcal{S}^t\, I = \mathcal{S}^{t+s}\, I, \qquad \forall s, t \geq 0.$$

d. (0.5pt) Show that this scale space is contrast invariant in the sense that

$$\mathcal{S}^t (gI) = g(\mathcal{S}^t\, I).$$

with g an arbitrary positive constant.

Problem 3. (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: $A = (0, 0, 3)$.

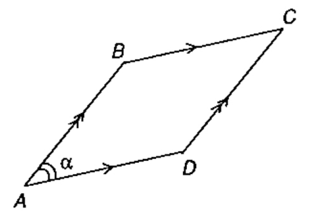

Figure 1: *Four line segments forming a parallelogram.*

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

$$V: \quad Ax + By + Cz + D = 0. \tag{3}$$

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

Problem 4. (2.5 pt) Consider a stereo pair of images from two cameras as shown below with $O_L = (-10, 0, 0)$ and $O_R = (10, 0, 0)$, $f = 20$

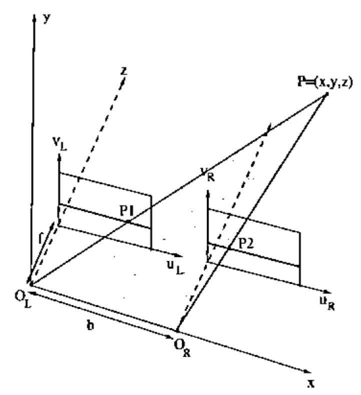

Figure 2: *Standard stereo set-up.*

a. (1.0 pt) The key to successful shape-from-stereo is solving the *correspondence problem*. A common approach is feature-based correspondence. Describe the approach and give a practical example of features that could be used.

b. (0.5 pt) Suppose a feature P is detected in the left camera image at $(u_L, v_L) = (0, 0)$. Where should we look in the right image for a corresponding feature?

c. (0.5 pt) Given the above observation, but in the absence of a matched point in the right image, what constraints on the (x, y, z) position can be given?

d. (0.5pt) Suppose P appears to match *two* points in the right image at $(u_R, v_R) = (-1, 0)$ and $(u_R, v_R) = (1, 0)$. Which is the correct match, and what is the (x, y, z)-position of the object?