Machine Vision, exam November 2014

You may write your answers in Finnish or English.

1. Briefly explain the following terms (6 p)

   (a) Radial distortion

   (b) K-nearest neighbour classification

   (c) HSV space

   (d) Specular reflection

   (e) Structured light

   (f) Camera extrinsics

2. Describe the main principles of the following and give one example of their usage:

   (a) Optical flow. (2 p)

   (b) SIFT descriptor. (2 p)

   (c) Quadtree. (2 p)

   (d) Hough transform. (2 p)

3. 2D transformations

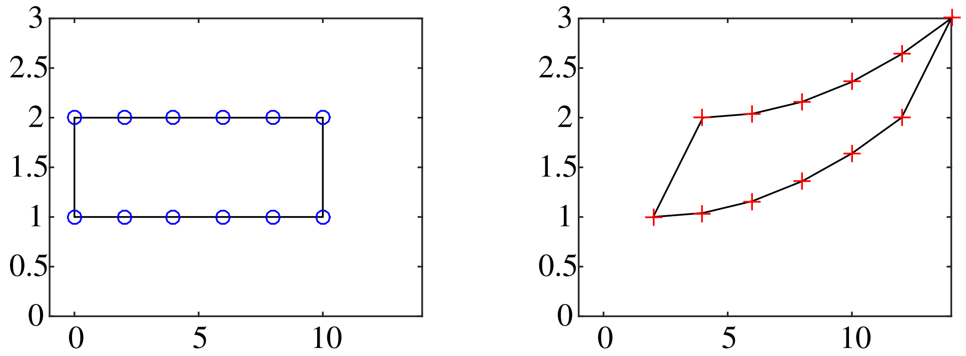

Figure 1: **Left:** rectangle before deformation. **Right:** rectangle after deformation.

A rectangle is deformed as observed in figure 1. It is known that the coordinates of the points deform through a function of the following form:

$$x' = ax + by$$
$$y' = cx^2 + dy$$

   (a) How many degrees of freedom does the transformation have? How many point correspondences are needed to estimate the parameters? (1 p)

   (b) Derive the equations to estimate the transformation parameters from a set of point correspondences. (2 p)
   Hint: the transformation can be estimated linearly through a system of the form $\mathbf{A}\mathbf{x} = \mathbf{b}$.

(c) Some points have been measured before and after the transformation, $\mathbf{p}$ and $\mathbf{p}'$ respectively.

$$\mathbf{p} = \begin{bmatrix} 0 & 2.00 & 4.00 & 6.00 & 8.00 & 10.00 & 10.00 & 8.00 & 6.00 & 4.00 & 2.00 & 0 \\ 1 & 1.00 & 1.00 & 1.00 & 1.00 & 1.00 & 2.00 & 2.00 & 2.00 & 2.00 & 2.00 & 2 \end{bmatrix}$$
$$\mathbf{p}' = \begin{bmatrix} 2 & 4.00 & 6.00 & 8.00 & 10.00 & 12.00 & 14.00 & 12.00 & 10.00 & 8.00 & 6.00 & 4 \\ 1 & 1.04 & 1.16 & 1.36 & 1.64 & 2.00 & 3.00 & 2.64 & 2.36 & 2.16 & 2.04 & 2 \end{bmatrix}$$

Recover the parameters a, b, c, d. (2 p)

4. Triangulation

We want to perform triangulation of 2D points using 1D cameras. Just like a 2D camera captures a 3D world onto a 2D image, our 1D camera captures a 2D world into a 1D image. The projection function for this 1D camera is expressed in homogeneous coordinates by:

$$\begin{bmatrix} m \\ 1 \end{bmatrix} \propto \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

where m is the pixel position, $[x, y]^\top$ is the point position in the 2D world, and p_{ij} constitute the 2×3 projection matrix. Note that the equality is up-to-scale because all quantities involved are in homogeneous coordinates.

(a) Two cameras with projection matrices $\mathbf{P}$ and $\mathbf{Q}$ observe the same point at m_p and m_q. Derive the equations to recover the point position $[x, y]^\top$ from the two projection matrices and measurements. (2 p)
Hint: the equations result in a linear system of the form $\mathbf{A}[x, y]^\top = \mathbf{b}$.
Hint: a pair of 2D vectors $\mathbf{a}$ and $\mathbf{b}$ are parallel to each other if $a_1 b_2 - a_2 b_1 = 0$.

(b) We have two cameras with known projection matrices:

$$\mathbf{P} = \begin{bmatrix} 1 & 2 & 0 \\ 2 & 1 & 0 \end{bmatrix} \quad \text{and} \quad \mathbf{Q} = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 2 & 0 \end{bmatrix}.$$

We have measured the same point $\mathbf{x}$ at positions $m_p = 1.1$ and $m_q = 0.7$. Triangulate the point and recover the position. (1 p)

5. Texture

Most texture operators are applied only to the intensity channel and do not take color into account. It is thus useful to also compare colors when comparing the texture measures. With this in mind, the feature vector for a point $v = [r, g, b, t_1, t_2, t_3]^\top$ includes the color components (r,g,b) and the texture measures (t_1,t_2,t_3).

The Euclidean distance is not well suited to compare two feature vectors v_1 and v_2 because the color and texture measures have different units. Give an equation for a distance measure between two feature vectors that takes this into account. (2 p)

Hint: you can use the covariance matrix of the feature vectors.