Problem Set 04

1. **(Variations of the Horn-Schunck Algorithm)** Implement the Horn-Schunck algorithm for optical flow calculation. Of course, there are already programs available for free use, but implement your own version.

   Test the algorithm on pairs of images showing a scene with only minor differences in between; motion should be limited to distances of 5-6 pixels at most. Use both mentioned strategies for initialization of *u*- and *v*-values (i.e. just 0 or the closest point *Q* to the origin *O* in the velocity space; see Example 4.1 in the textbook).

   Use also two different approximation schemes for I_x, I_y, and I_t. Discuss the impacts of those different options on your flow results. After each iteration step *n* + *1*, calculate the mean of all changes in *u*- and *v*- values compared to the previous step *n*. Display those changes over the number of iterations.

   Would it be possible to use a threshold for those changes for defining a stop criterion for the algorithm? Discuss how many iterations you consider as being sufficient for your input sequences and how this is influenced by the used initialization scheme and the selected approximation schemes for I_x, I_y, and I_t.

2. **(Mean-Shift Segmentation in *OpenCV*)** The function *meanShift* in *OpenCV* uses parameters for spatial radius (*sp*), color radius (*cr*), and used levels in the image pyramid (*L*). Parameter *k* =*sp* defines the window size (2*k* + 1) × (2*k* + 1) in the spatial domain (i.e. carrier *Ω*). The parameter *cr* defines the window size in the feature space with “feature = color” (i.e. consider all values (R, G, B) with:

$$\left\| (R, G, B) - (R_0, G_0, B_0) \right\|_1 \leq \mathtt{cr}$$

   where (R_0,G_0,B_0) is the image value at the current pixel.

   The parameter *L* = *maxLevel* is greater than or equal to 0; this means that a pyramid of L + 1 levels is used. **Fig.2** illustrates results for *L* = 1 (i.e. two levels); the top row illustrates the application of subsequent segment coloring using the function *floodFill*.

   Discuss the meaning and impacts of the parameters *cr*, *sp*, and *L* with reference to provided explanations in this chapter and by using images of your choice, also including the image *Spring* (Fig. 5.28 in page 201 of the textbook), as an example for a difficult segmentation.

Fig. 2. *Top*: Segmentation results for the image Aussies, where segments are pseudo-colored rather than shown with the image value identified at the peak. Use of *sp* = 12 and *sr* = 19 (*left*), or use of *sp* = 5 and *sr* = 24 (*right*). *Bottom*: The image *Xochicalco* (*left*) and segmented image (*right*) using *sp* = 25 and *sr* = 25.

3. **(Detection of Calibration Marks)** Record images for camera calibration using a checkerboard pattern as illustrated in Insert 6.3 in page 232 of the textbook. Implement or use an available program for line detection (see Section 3.4.1) and detect the corners in the recorded images at subpixel accuracy. Discuss the impact of radial lens distortion on your detected corners.