Exercise 3D Machine Vision

Sample solution

Prof. Dr.-Ing. Volker Willert

Exercise sheet 4

In this exercise we will deal with the *correspondence problem,* feature *search* and *descriptors,* as well as *scale spaces* (image pyramids) and *optical flow.* The questions are detailed and can be seen as examples of potential exam questions.

Task 4.1: Correspondence problem

4.1a)

Name two applications of image processing where the correspondence problem can occur.

Answer: Stereo vision, optical flow calculation

4.1b)

In which pattern can correspondence be clearly found?

Edge

homogeneous surface

repeating texture

× Corner

transparent surface

Patterns with strong differences in the distance between individual pixels

× point

4.1c)

For which categories does it make sense to choose between discrete and differential correspondence search algorithms ?

Object moving vs. camera moving

× small base distance vs. large base distance when viewing a static scene

individual pixels in the image (sparse) vs. all pixels in the image (dense)

× small shifts vs. large shifts

4.1d)

What else is the correspondence problem called?

Answer: Aperture problem

Task 4.2: Feature search

4.2a)

What does the autocorrelation function measure?

Answer: The self-similarity of a signal.

4.2b)

To which range of values is the normalized autocovariance function limited?

Answer: The values are between [ÿ1; 1].

4.2c)

Which measures are invariant to differences in brightness?

Autocorrelation

× Cross covariance

Cross-correlation

× normalized autocovariance

× Autocovariance

× normalized cross covariance

× SSD Matching

4.2d)

Which measures are invariant to contrast differences?

Autocorrelation

Cross covariance

Cross-correlation

× normalized autocovariance

Autocovariance

× normalized cross covariance

SSD Matching

4.2e)

Which statistical measure is needed to compensate for contrast differences? How must this measure be calculated with the pattern so that the pattern is contrast-normalized?

Answer: The variance or the standard deviation. It must be divided by the standard deviation.

Task 4.3: Interest Points & Descriptors

4.3a)

Which detectors or descriptors can be used to measure coordinates precisely?

SIFT descriptor

× Shi-Tomasi corner point detector

HoG Descriptor

Threshold on determinant of the Hessian matrix

× Harris Corner Detector

4.3b)

Explain how the SIFT descriptor generates a feature vector from HoGs. You can also make a sketch.

Answer: The SIFT detector divides a 16 × 16 pixel image section into 16 non-overlapping cells of size 4 × 4. For each cell, a HoG descriptor is generated over 8 different gradient orientations. The frequencies of all these 16 HoGs are written into a feature vector of size 16 × 8 = 128.

4.3c)

Name two variations between views that feature search based on the SIFT descriptor can handle well.

Answer: Differences in brightness, larger out-of-plane rotations, different scaling

4.3d)

How must features be distributed in the feature space to be discriminatory? Show this using an example in the 2D feature space for features of three different classes.

Answer: The feature vectors of the same class should be close to each other in the feature space and the feature vectors of different classes should be as far apart as possible in the feature space.

Task 4.4: Scale spaces

4.4a)

Which image pyramids are used in image processing?

Cheops Pyramid

× Laplace Pyramid

Tensor pyramid

× Gauss pyramid

Pixel Pyramid

4.4b)

Explain how a Gaussian pyramid is calculated recursively and which theorem must not be violated?
How much memory does the pyramid require compared to the original image?

Answer: Starting with the highest image resolution (original image), the image is low-pass filtered with a 3×3 binomial filter, then the image is downsampled, with only every second pixel being sampled in each dimension. This does not violate the sampling theorem. This process is repeated recursively until the desired scale is reached or only one pixel remains. The memory requirement is only 1/3 higher than that for the original image.

4.4c)

What filtering properties does the Laplace pyramid have? How can you create a Laplace pyramid from a Gaussian pyramid ?

Answer: The Laplace pyramid corresponds to a bandpass filter bank. The Laplace pyramid is created by calculating the difference between neighboring scales of the Gaussian pyramid. To do this, the coarser resolution must be adjusted to the finer one by upsampling (in the simplest case by quadrupling each pixel).

Task 4.5: Optical flow

4.5a)

What is the name of the most well-known classical optical flow method?

Answer: Lucas-Kanade method

4.5b)

What is the difference between the motion field (displacement vector field) and the optical flow?

Answer: The motion field corresponds to the difference vectors that result from the projection of each 3D point onto a moving image plane at different times. The optical flow corresponds to the shift of all gray values in the image, assuming that the gray values do not change during the shift. Analogous to the continuity equation for a liquid, where the mass flow remains constant during stationary or incompressible flow through a volume body. A certain gray value therefore corresponds to a certain mass.

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4.5c)

What two assumptions are made in SSD matching to calculate a displacement vector?

Answer: Brightness constancy assumption, neighboring flux vectors are identical.

4.5d)

Which correlation measure does the Lucas-Kanade method use as a quality measure?

- SAD matching
- local cross-correlation function
- × SSD matching
- local cross-covariance function
- SPD matching

4.5e)

Which 1D subspace results for a 2D displacement vector from the constraint of brightness constancy?
At what point in the subspace is the normal flow vector located? Draw a sketch to explain.

Answer: The result is a straight line. The normal flow points along the gray value gradient. See also slide set 5, slide 79.