2022-2023 Computer Vision

Sheet 1

1) **RANSAC** (**RAN**dom **SA**mple **C**onsensus) is an algorithm for fitting a model to very noisy data. Its basic idea is to fit models to small samples of data, and then look for "consensus" from the entire dataset.

i. Define ONLY the used parameters of the RANSAC algorithm, and how the value of each parameter should be selected.

Solution:

- s: minimum number of sample points needed to fit the model
- Distance threshold T : it's chosen so probability for inlier is high
- Number of iterations N: chosen so that, with probability p, at least one random sample set is free from outliers

Adoptive procedure for choosing N:

- N=∞, sample_count =0, e = 1.0
- While N > sample_count
  - Choose a sample and count the number of inliers
  - Set $e_0 = 1 - \frac{number\ of\ inliers}{total\ number\ of\ points}$
  - If $e_0 < e$ Set $e = e_0$ and recompute N from e:

N > log (1-p) / log (1-(1-e)^s)

Increment the sample_count by 1

ii. Using RANSAC for fitting a translational model, suppose we know that 30% of our data is outliers. How many times do we need to sample to assure with probability 80% that we have at least one sample being all inliers?

Solution:

N > log (1-p) / log (1-(1-e)^s)

P = 0.8 e = 0.3 , s= 1

N > log(1-0.8)/ log (1-(1-0.3))

N> log(0.2)/log(0.3)

N> 1.336

N=2

2) In the **Harris** feature detector, describe what is the second-moment matrix? Explain its role and how this is used to select good features.

- From slides

3) Many Computer Vision algorithms such as **SIFT** (Scale-Invariant Feature Transform) seek to detect and analyze features at multiple scales of analysis.

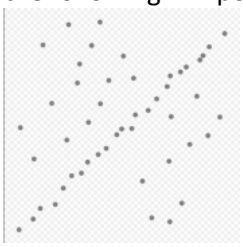
i. Explain briefly what is scale-space?

ii. For what operation is the **DoG** (Difference-of-Gaussian) used in different scale levels? Show its advantage over **LoG** (Laplacian-of-Gaussian).

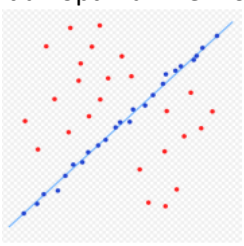
iii. A SIFT descriptor for a 16×16 image window W is a vector of 128 numbers, which can be thought of as being grouped in 16 consecutive groups of 8 numbers each. What does each group of 8 numbers represent?

From slides

4. Given the following 2-D point cloud, it is supposed to fit an optimal line model to it.



(a) Original point cloud



(b) Line model after fitting

i. Describe how you will use **RANSAC** algorithm for the aforementioned task.

ii. Assume that there are 60% inliers; compute the minimal number of RANSAC iterations needed to get, with probability 95%, at least one random sample that is free from outliers.

Solution:

$N > \log (1-p) / \log (1-(1-e)^s)$

$P = 0.95\ e = 0.4\ ,\ s= 2$

$N > \log(1-0.95)/ \log (1-(1-0.4)^2)$

$N> \log(0.05)/\log(1-0.36)$

$N> \log(0.05)/\log(0.64)$

$N> 6.712$

$N=7$

5. What feature detector would you use to propose a set of probable correspondences between two images of the same object, but taken with a different rotation and zoom setting? SIFT

Explain only the step(s) of how this feature detector is set to be rotationally invariant?

From slides

6. A feature descriptor is a representation of an image that simplifies the image by extracting useful information and throwing away extraneous information. Typically, a feature descriptor converts an image of size width x height x 3 (channels) to a feature vector / array of length n.

i. State what are the characteristics of a good feature descriptor?

Solution:

- *Repeatability/Precision: The same feature can be found in several images of the same scene despite geometric and photometric transformations*
- *Saliency/Matchability :* Each feature has a distinctive description
- *Compactness and efficiency :* Many fewer features than image pixels

Locality: A feature occupies a relatively small area of the image; robust to clutter and occlusion

ii. Explain the steps of the ***Histogram of Oriented Gradients (HOG)*** feature descriptor.
From slides

7) ***RANSAC*** (RANdom SAmple Consensus) is an algorithm for fitting a model to very noisy data. Its basic idea is to fit models to small samples of data, and then look for "consensus" from the entire dataset. Complete the following pseudo-code for RANSAC

INPUT:
data - a set of observations
model - a model that can be fitted to data
s - the minimum number of data required to fit the model (fixed for a given model)
t - a threshold value for determining when a data point fits a model
d - the number of "consensus" data points required for a "good" model

OUTPUT: BestModel
FOR (a number of iterations)
    CurrentSet := sample a data subset of size s
    CurrentModel := model fitted to CurrentSet
    ConsensusSet := CurrentSet
    FOR every data point not in CurrentSet
        IF (CurrentModel(point)>t) // the point fits in CurrentModel
        Add point to ConsensusSet
        END IF
    END FOR
    IF #(ConsensusSet) > d
    BestModel = ConsensusSet
    Break
    END IF
END FOR
RETURN BestModel

8) Describe the Harris detector for corner detection of a 2D image by giving the main steps of the algorithm with description of the used parameters
From slides