Development of a stereo matching algorithm

1) Objective

Project's objective is the development of an algorithm that, given a pair of rectified stereo images, computes the associated disparity map. Then, the experimental results obtained by the developed algorithm must be evaluated quantitatively.

2) Dataset

The *dataset* provided to students contains the rectified stereo pairs that must be used to evaluate the experimental results (file *stereodataset.zip*). This *dataset* has been downloaded from the well-known *Middlebury Stereo Vision Page* (vision.middlebury.edu/stereo).

The *dataset* consists of the 4 folders:

- *Tsukuba*
- *Venus*
- *Cones*
- *Teddy*

tsukuba (*left image*)

tsukuba (*right image*)

each folder containing:

- 1 pair of rectified stereo images, called *imL.png* e *imR.png* (the left and right images of the stereo pair, respectively);
- the *ground-truth* (error-free) disparity map associated with the reference image, which, in the provided dataset is always the left image of the pair. The ground-truth disparity map is called *groundtruth.bmp*

- a text file specifying the parameters to be used with the pair :

    - the *disparity range* associated with the stereo pair (specified by the parameters *disp_min*, *disp_max*),
    - the scale factor needed to obtain a disparity map coherent with the *ground-truth* disparity map (specified by the parameter *disp_scale*),
    - the width of the image border to be ignored when evaluating the experimental results.

An exemplar text file is provided below:

disp_min 0
disp_max 15
disp_scale 16
ignore_border 18

3) Specifications

3.1) First task: development of a baseline stereo matching algorithm (*mandatory*)

Students are required to develop an *area-based* stereo matching algorithm based on comparing pixel intensities within windows centred at candidate corresponding points. More precisely, for each point in the reference image, the window centered at the point is compared to all those centered at the points in the other image laying on the same row and within the disparity range. The comparison between windows must be carried out according to the SAD (*Sum of Absolute Differences*) dissimilarity function. The window providing the lowest SAD determines the corresponding point in the other image and thus the disparity value for the given point in the reference image (*winner-takes-all approach*).

Then, results must be evaluated quantitatively according to the methodology described in Section 4.1. Based on analysis of the obtained results, students should also comment on the main issues that cause errors when computing disparities by the baseline algorithm.

3.2) Second task: improving the baseline algorithm (*optional*)

Based on the issues highlighted by the experimental evaluation, students should develop a modified *area-based* stereo matching algorithm capable to deliver more accurate results.

Improvements to the baseline algorithm may concern one or more of the following items.

- Detection of low-textured points in the reference image (perhaps by the Moravec operator) so to avoid computing disparities therein.
- *Left-right check:* matching images both from left to right and from right to left, so to reject incoherent matches.
- Analysis of the dissimilarity function within the disparity range, so to accept a match only in case of a sharp and unambiguous minimum.
- Deployment of a more robust function (such as the NCC, ZNCC…) than the SAD to compare windows.
- Filtering the stereo images, by e.g. a low-pass or band-pass filter, before carrying out the matching process.
- Improving the discriminative power of the matching process by relying on color rather than gray-scale image (so to better highlight the differences between windows).
- ….

It is worth pointing out that, as several of the above improvements imply discarding potentially wrong matches, the disparity maps provided by the modified algorithm may not turn out dense, as instead are those delivered by the baseline one.

The results provided by the modified algorithm should be evaluated quantitatively according to the methodology described in Section 4.2. The new results should be discussed and, in particular, compared to those yielded by the baseline algorithm.

4) Quantitative evalation of the experimental results

4.1) Evaluation of the results provided by the baseline algorithm

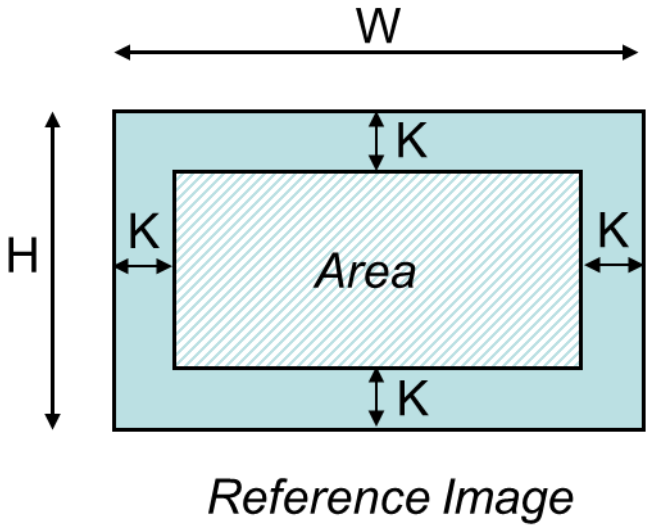
Results should be evaluated quantitatively by comparison to the available ground-truth. More precisely, students should rely on the Error function, $\boldsymbol{E}$, defined below:

$$E = \frac{\sum_{p \in Area} S(p, p_{gt})}{N_{Area}}$$

where function $S(p, p_{gt})$ is 1/0 depending on the absolute difference between the disparity, p, computed at a pixel of the reference image and the associated *ground-truth* disparity, p_{gt}, being greater/less than 1:

$$S(p, p_{gt}) = \begin{cases} 1, & |p - p_{gt}| > 1 \\ 0, & \textbf{\textit{otherwise}} \end{cases}$$

Area and N_{Area} represent, respectively, the area of the reference image within which the matching process can be executed and the number of pixel in that area. As illustrated below, *Area* is the central region of the reference image whose size depends on that of the window used for the matching process, which is assumed here squared and having size *(2K+1)* ×*(2K+1)* pixel, so that $N_{Area} = (W - 2K) \cdot (H - 2K)$.



4.2) Evaluation of the results provided by the modified algorithm

In case the modified algorithm does not provide a disparity at each pixel within *Area*, only those pixels featuring a valid disparity value should be taken into account to compute both the numerator and denominator of function *E*. Moreover, the fraction of pixels in *Area* where disparity has not been computed must be evaluated, and, possibly, such a fraction studied jointly together with the error *E* while varying a key parameter, so to highlight the trade-off between accuracy and density of the disparity map yielded by the modified algorithm.

In case the modified algorithm provides dense disparity maps, just as the baseline algorithm does, the quantitative evaluation can be carried out exactly as described in Sec. 4.1.