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Evaluation of the precision of close-range photogrammetry to assess DEM of the soil surface.

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Close-range photogrammetry is a quick and flexible tool to assess digital elevation model (DEM) of the soil surface on small scale in the order of $1m^2$. Moreover, it can be used under rainfall and may be helpful to monitor rainfall induced changes of the soil surface roughness or to quantify erosion at a local scale. However, this method relies (i) on a very precise calibration procedure of the system of 2 cameras (to get the interior and exterior geometric parameters and to allow the process of epipolar rectification) and (ii) on a statistical correlation between every pixels of both images to obtain the disparity map. Therefore it is necessary (i) to check the stability of the interior parameters of both cameras, (ii) to study the sensitivity of the computed DEM to the interior and exterior parameters, (iii) to propose an optimal configuration for the data acquisition in the field. This study deals with the interior parameters only. We used a pair of Nikon D100 digital cameras (6 Mpixels CCD, 35 mm lens), a commercial software (Halcon, MvTec, Germany) and the associated calibration target composed of 49 black spots equally distributed on a 500 mm x 500 mm white plate, with a precision of 0.1 mm. Interior parameters (focal length /m, coefficient of radial distortion /m-2, cell size of the CCD /m, pixel coordinates of the principal point Cx and Cy /pixel), are estimated with an iterative non linear optimization method. The objective function to minimize is the distance between the projection of the calibration marks onto the image plane and the marks locations extracted from the image (RMSE). 9 optical settings were studied (3 camera-to-target distances (1.5m, 3m, 4.5m) x 3 apertures (F4, F8, F16)). For each optical setting, 30 images of the calibration plate were taken. The calibration process was then conducted on the whole images set and on

3 sub-samples of 5, 10 and 20 images respectively (50 samplings for each subset). Finally, the calibration process was performed 9x(3x50+1)=1359 times. For each calibration, we obtained the interior parameters and the RMSE on the X axis (RMSE_X) and on the Y axis (RMSE_Y). A statistical analysis was performed on the parameters, on their correlation and on the RMSE. Interior parameters are not correlated except RMSE_X and RMSE_Y that are equal: no anisotropy can be found in the image acquisition process. The RMSE is always less than 0.2 pixel on the image plane (which corresponds to 65 μm on the target plane), but the fitted parameters are not unique and their variability decreases with the size of the image subset. In some cases (subsets of 5 and 10 images), fitted parameters have no physical meaning. The aperture and the camera-to-target distance have only a limited influence on the calibration process, but a distance of 3m and a F8 aperture yield to the smallest RMSE and to the best defined parameters when associated with a set of more than 20 images. This study was useful to check the stability of the interior parameters and to determine optimal configuration for the data acquisition in the field. The influence of the interior parameters on the precision of the reconstructed DEM still needs to be assessed through further study.