Multiplane calibration tutorial

In this tutorial we will work with four cameras and a target plane imaged at five different positions along the *z* axis. In your *test/cal* folder rename the images of the first plane as *calib_a_cam#.tif* where # is the camera number. Rename the images of the four remaining planes (*b* to *e*) using the same naming convention. For each camera and each plane, the software needs an *.ori* file that contains the position and orientation of the camera in the three-dimensional coordinate system and some of its intrinsic parameters (focal length and principal point offset). Create and rename these files following the same naming convention (e.g. *calib_a_cam1.tif.ori).* Each *.ori* file is organized as follow:

X	Y	Z	**Position of the center of projection (mm)**
α	β	γ	**Camera rotation vector (gon)**
	R_{ij}		**Camera rotation matrix (not used during the initial guess)**
a	b		**Principal point offset (µm)**
f			**Focal length (mm)**
x	y	z	**Position of the interface (mm)**

1) Single-plane calibration

The first step is to perform a single-plane calibration on each plane. In this example, we start with the plane *a*. In *Change Parameters/Change Calibration Parameters* update the path and name of your calibration images and orientation files. Set up the path and name of your target file that contains the three-dimensional coordinates of the target dots (in our case *cal/a_target_plate.txt*). The first column contains the point numbers. The second, third and fourth columns contain the *x*, *y* and *z* positions of the target dots, respectively. In each image, select four clearly visible dots on the calibration plate. These points will be used later during the pre-orientation procedure. They can be the same or different in the four images, and should be far from one another. In this example, we will select the four points at the corners of the plate. Adjust the *Target recognition on plate* parameters. In *Orientation parameters* the boxes *Calibrate with different z-positions* and *Combine preprocessed planes* remain unchecked. Do not allow for the focal length and principal point offset to be adjusted (Fig. 1).

In the *Calibration* menu, click on *Show Calib. Image* and then on *Detection*. Adjust the pixel intensity threshold for each image and the particle detection parameters in the *Change Parameters/Change Calibration Parameters* menu until most of your calibration dots are detected. Wrong detections caused by dust particles and reflections or scratches on the glass of the aquarium may prevent the calibration to converge; adjust the detection parameters carefully and discard wrong detections. Click on *Calibration*/*Manual orientation* and for each image click on the positions of the four points that you have previously defined in *Change Parameters/Change Calibration Parameter/Point number for manual pre-orientation*. Click on *Calibration*/*Orientation with file* and check that you have clicked on the right points (Fig. 2). Click on *Calibration/Show initial guess*. If your orientation files contain a good estimation of the orientation parameters of the cameras, the projected positions of the calibration targets with appear as yellow dots in the image of the corresponding camera (Fig. 3). If not, their virtual image coordinates are displayed anyway in the terminal window. Click on *Calibration/Sortgrid*. The software labels every detected points; the shift between the projected positions and the detected target points is normal (Fig. 4). Click on *Calibration/Orientation* (Fig. 5). If the calibration algorithm converges, the software overwrites the *.ori* files with the results of the calibration. The software returns the root mean square of the calibration error in the terminal window. Repeat all the steps for the four remaining calibration planes. Restart the software between each single-plane calibration and whenever the orientation procedure does not converge or leads to inconsistent orientation values. Back up your *cal* folder before proceeding with the next plane.

2) Multiplane calibration

The software will combine the calibration data obtained during the five single-plane calibrations and perform a calibration on a virtual three-dimensional target block. First edit the *multi_planes.par* file in the *test/parameters* folder. This file defines how many planes you use, and the base name of each plane (Fig. 6). In *Change Parameters/Change Calibration Parameters*/*Calibration Parameters*, change the names of the calibration images and orientation files (Fig. 7). Set both *Calibrate with different z-positions* and *Combine preprocessed planes* to one, and allow for the focal length and principal point offset to be adjusted. In the *Calibration* menu, click on *Show Calib. Image* and then directly on *Orientation*. The calibration results are displayed in the terminal window and written to the *.ori* files (in our case *calib_m_cam#.tif.ori*).

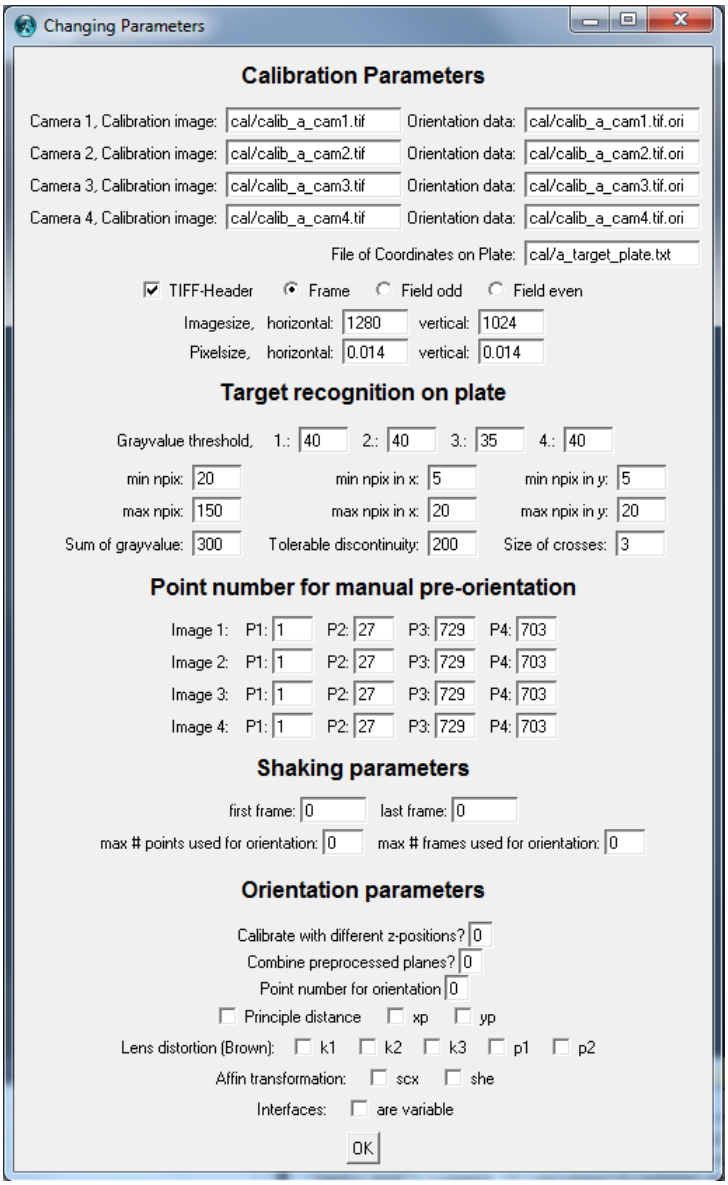

Fig. 1. The Change Parameters/Change Calibration Parameters menu (for single-plane calibration).

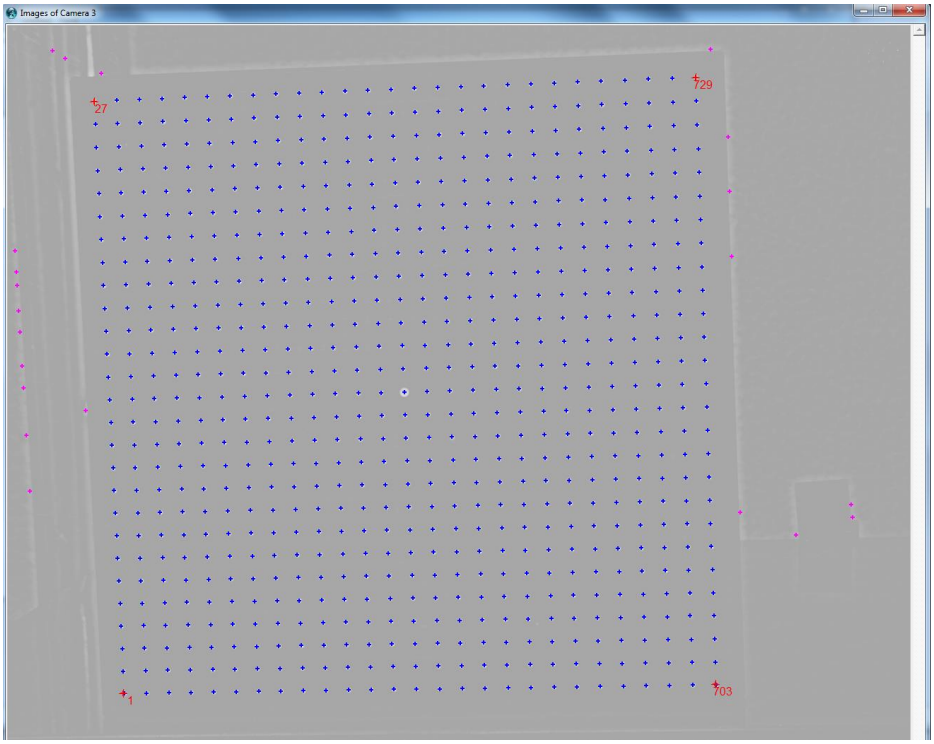

Fig. 2: Calibration/Orientation with file.

Fig. 3. Calibration/Show initial guess.

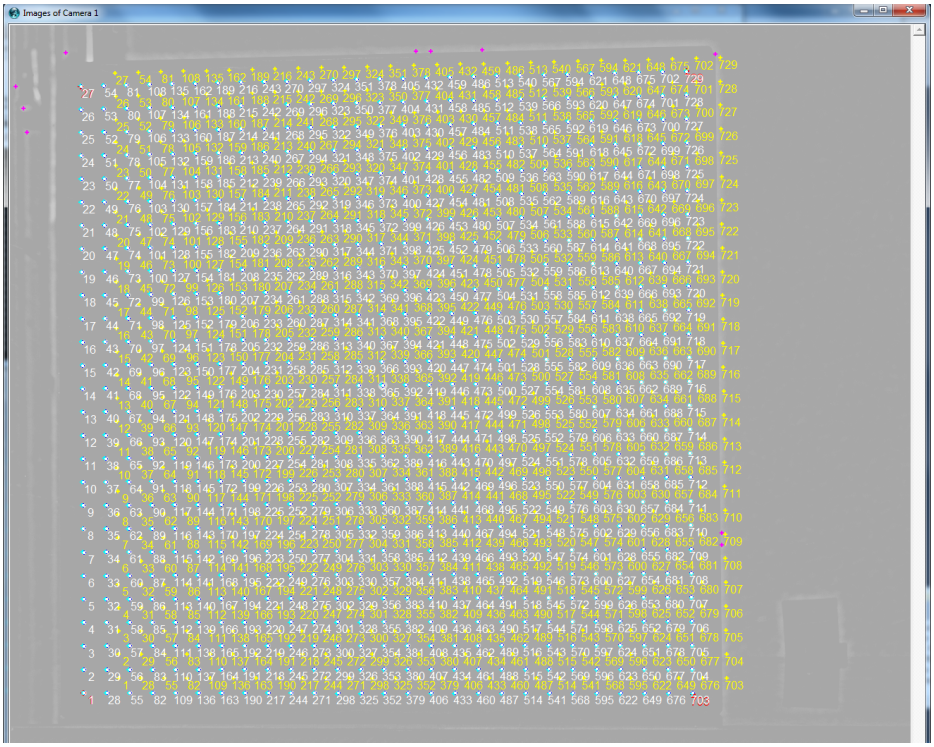

Fig. 4. Calibration/Sortgrid.

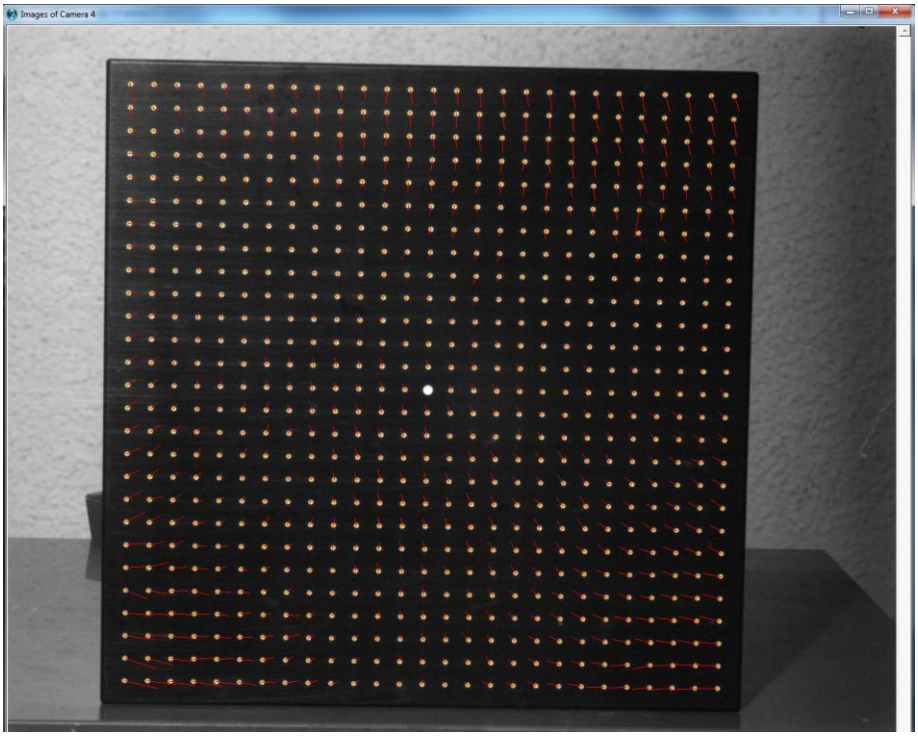

Fig. 5. Calibration/Orientation.

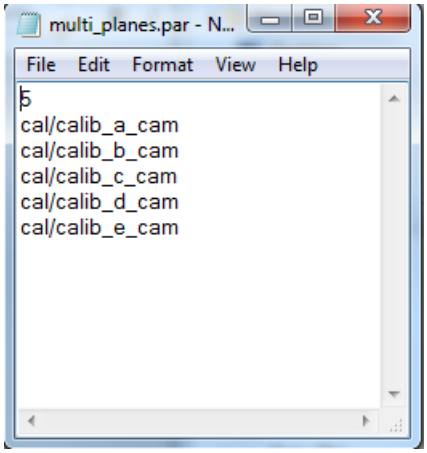

Fig. 6. Content of the test/cal/multi_planes.par file.

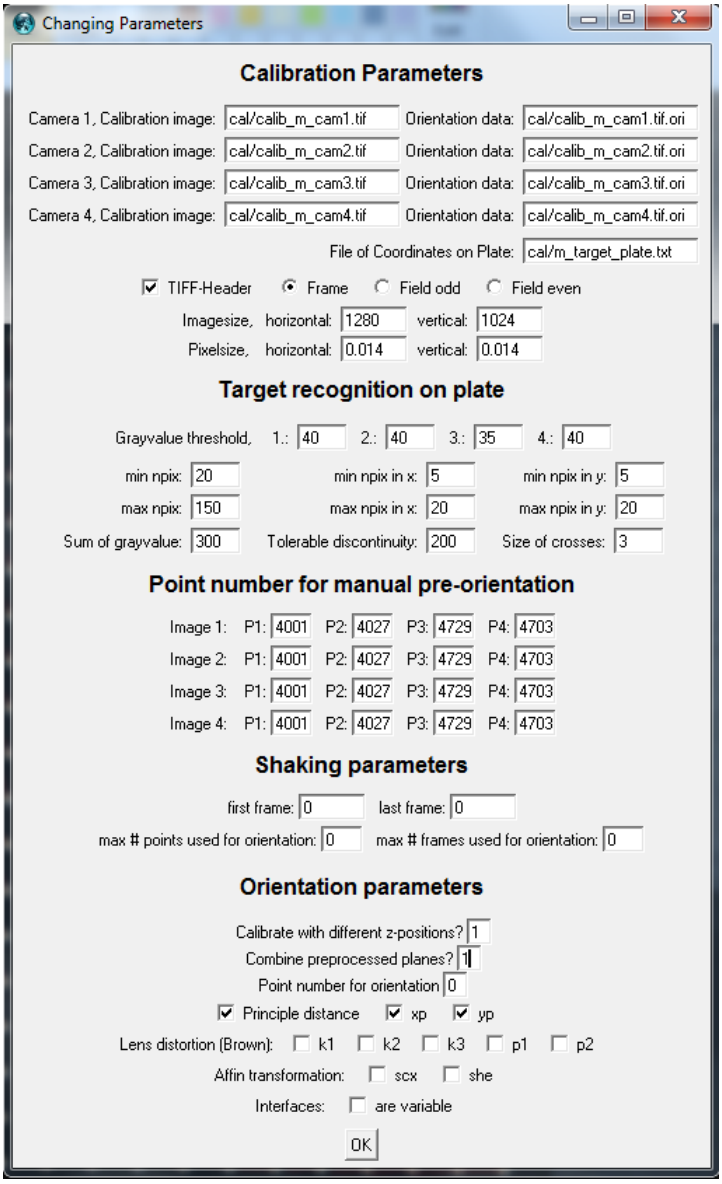

Fig. 7. The Change Parameters/Change Calibration Parameters menu (for multiplane calibration).