Stereoscopic Mapping with Thermal Infrared Images

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ABSTRACT

Thermal infrared cameras using an imaging array, do have similar geometric conditions like perspective photos. So a geo-reference of the determined object temperatures is possible by means of orthophotos. A sufficient geometric accuracy requires the knowledge of the image geometry which is not available by the factory. A first test of the used ThermScan camera by self calibration with bundle block adjustment of a flight over a dump, failed because of problems with the exact image tie. The tie points in thermal infrared images cannot be measured with the same pixel accuracy like in corresponding photos based on the visible spectrum. The gray values are based on differences of the object temperature which is usually limited and edges are not so well defined. By this reason a laboratory calibration with a test field, marked by small bulbs, was made. Depending upon the used optics, radial symmetric distortions of 1 pixel and not symmetric distortions of 1.5 pixels have been determined.

Based on the geometric calibration, a block adjustment is possible. This is the required geometric information for a stereoscopic mapping and the creation of orthophotos with thermal infrared images.

INTRODUCTION

The thermal camera ThermScan images the object with an array of 272 x 136 pixels under perspective condition. This simplifies the georeference of images taken from aircraft. It is not necessary to combine the camera with an expensive combination of GPS and an inertial measurement unit (IMU) like in the case of scanning instruments. The perspective thermal images can be handled like usual metric photos, that means, information about the inner orientation must be available. This includes the focal length, the location of the principal point and the imaging geometry – mainly the radial symmetric distortion, but also other effects.

The Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover, Germany, liked to use the thermal camera ThermScan for investigations of volcanic areas. The change of the ground temperature can indicate coming eruptions, enabling an evacuation of the local population in time. The analysis of a temporal change of the temperature requires a sufficient geo-reference, which is possible by orthophotos. For the orthophoto production, information about the exterior and interior orientation are required as well as a digital height model. The contrast and resolution of thermal images is not sufficient for the creation of a digital height model, this has to be determined by the traditional method – usually based on aerial photos. For the support of thermal images also small format cameras or even digital cameras can be used. The determination of the exterior orientation of the thermal images can be made by classical bundle block adjustment with tie and control points, but it requires information about the inner orientation which will not be delivered by the factory in a calibration certificate, like for photogrammetric cameras.

CAMERA CALIBRATION

The camera calibration can be made under flight conditions by bundle block adjustment with self calibration by additional parameters or in a laboratory. If it is possible to calibrate the camera under usual working conditions, that means with aerial images, which shall be used also for the later production, this should be preferred. The geometric condition in the laboratory may be different, causing not optimal results. With vertical images from aircraft, the focal length and the location of the principal point can only be determined if control points with larger difference in the height are available. By this reason at first images of a salt dump, located close to Hannover, with height differences up to 70m, have been taken and used for a bundle block adjustment. The determination of the image orientation by bundle block adjustment with the Hannover program system BLUH was possible, but caused by the limited contrast, the tie point determination was not very accurate, so the inner orientation could not be determined with a satisfying standard deviation.

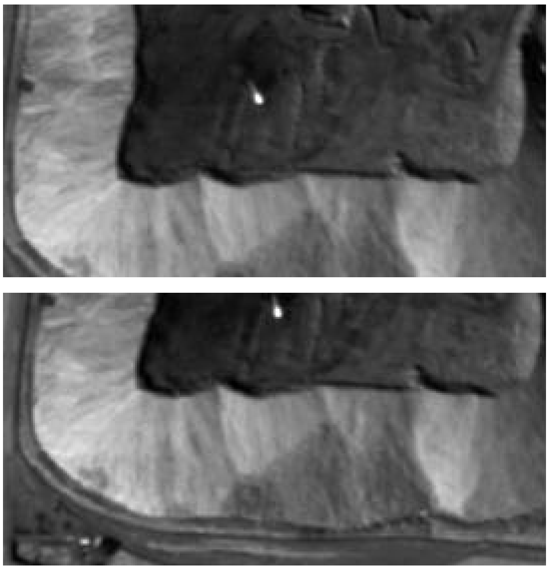

figure 1: thermal images of a salt dump

By this reason, a laboratory calibration was preferred. On an open frame with a dimension of 1.3 x 1.5 x 0.55m³ Christmas-bulbs have been mounted to generate a three-dimensional test field with good contrast (fig. 2).

For the ThermScan of the BGR two optics are available. No exact information about the focal length was given, but together with the focal length also the pixel size is required with the same accuracy. The photogrammetric information is based on the angles from the projection center to the object points and it doesn't matter if the image coordinates as well as the focal length are available in [mm] or [pixel] –only the relation focal length to pixel size is important.

The optics are named normal angle and wide angle, but this does not correspond to the definition of the usual aerial cameras – a wide angle camera with a focal length of 153mm and 230mm image size has a field of view (FOV) of 73.8° and a normal angle camera with 305mm focal length 41.3°.

format size	"normal angle" f = 752 pixels	"wide angle" f = 360 pixels
272 pixels	20.5°	41.2°
136 pixels	10.3°	21.3°

table 1: image size and field of view of the ThermScan

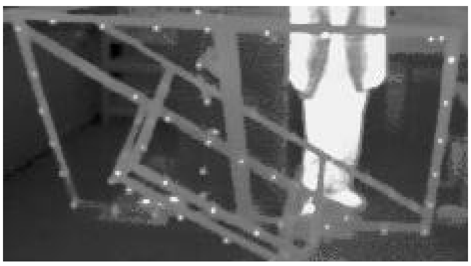

figure 2: thermal image of the test field in the laboratory

In a laboratory, images of the test field with both optics have been taken from different directions and different rotations around the view direction. It was more simple to fix the camera and rotate the test field than reverse, but for the final solution this has no effect. The calibrated coordinates of the test field have been determined by means of a Rolleimetric 6006 photographic camera with an accuracy better than 1mm. 1mm in the object space corresponds to 0.15 pixel in the thermal camera.

With 14 images, rotated against the perpendicular view up to 43°, a self calibration of the wide angle camera has been computed with the Hannover bundle block adjustment program system BLUH. Each of the 59 object points have been measured in the average in 10.3 photos. The inner orientation was determined together with the "systematic image errors" – the deviation between the mathematical model of perspective images and the real image geometry. This includes the focal length, the location of the principal point, the radial symmetric lens distortion and the remaining deviations. Within the standard deviation of the determination, the principal point is located in the center of the image. The image coordinates have had the dimension [pixel], corresponding to this, the whole result of the calibration corresponds to this. The focal length was determined with 360 pixels ± 1 pixel.

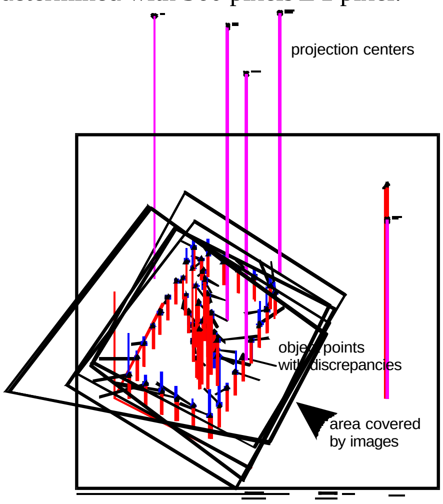

figure 3: calibration configuration for the wide angle lens

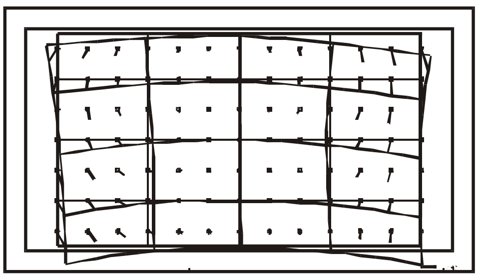

figure 4: systematic image errors of the wide angle camera, maximal size: 1.5 pixels

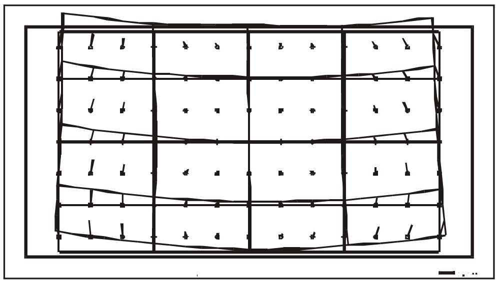

figure 5: systematic image errors of the normal angle camera, maximal size: 1.7 pixels

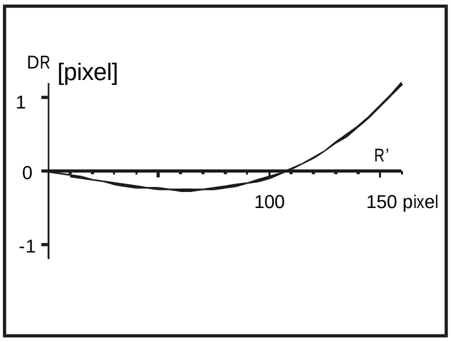

figure 6: radial symmetric lens distortion of the wide angle lens

A corresponding adjustment has been made with the normal angle data. Also here, the principal point is located in the image center. The focal length of 752 pixels is available with ±4 pixels. The systematic image errors (fig. 5) are similar to the normal angle, but it is bend in the opposite direction. The radial symmetric lens distortion goes up to 1 pixel (fig. 6), that means it is not so important. The pixels do not have an exactly square size – in the x-direction (line) the pixel values have to be multiplied with a factor 0.98. Both bundle block adjustments have been made with a $\sigma o = \pm 0.2$ pixel (accuracy of the image coordinates). That means, the ThermScan can be handled with the achieved calibration data like a metric camera.

MAPPING WITH THE THERMAL CAMERA

The described camera calibration was required for the geo-reference of images taken by the BGR over an volcanic area in the Philippines. There are not enough control points for the individual orientation of the images, so an orientation by bundle block adjustment was necessary. This requires a sufficient overlap of the photos, which are connected by means of tie points. The bundle block adjustment includes also the advantage of the three-dimensional determination of the ground coordinates of the tie points, that means especially the hot spots can be determined directly. Based on the image orientation a mapping in models is possible, but this is not the optimal method because of the limited image resolution. The limited image size of 272 x 136 pixels makes it difficult to map areas with low contrast, but these areas are not so important. The best solution is a combination of the ThermScan with a medium size photogrammetric camera. These images can be used for the determination of a digital height model, enabling the creation of a thermal orthophoto map, which can be used for the analysis of the temporal changes.

ACKNOWLEDGMENT

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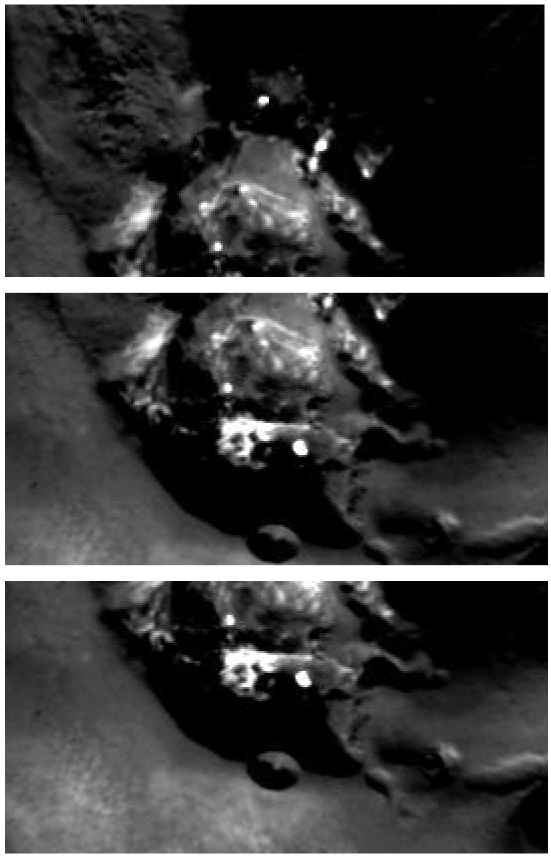

figure 7: thermal images of a volcanic area