OSIRIS

Optical, Spectroscopic, and Infrared Remote Imaging System

OSIRIS camera distortion correction parameters

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1 General aspects

1.1 Scope

This document describes the method, parameters, and validation for correcting the OSIRIS Narrow Angle Camera (NAC) and Wide Angle Camera (WAC) geometric distortion.

1.2 Introduction

The OSIRIS NAC utilizes a three mirror and the WAC a two mirror anastigmat optical system. Both cameras have high transmission over the UV-VIS-NIR spectral bands, and a chromatic aberration free, near diffraction limited performance. However, the asymmetric optical setup introduces a relatively high image distortion. This effect can be effectively corrected by resampling the image according to the calculated or measured two dimensional distortion function.

1.3 Reference Documents

no.	document name	document number, Iss./Rev.
RD1	OSIRIS user manual	RO-RIS-MPAE-UM-004, D/s
RD2	OSIRIS Calibration Pipeline OsiCalliope	RO-RIS-MPAE-MA-007, 1/d

2 Distortion correction

2.1 Correction method

The camera distortion is measured (or calculated) over the full field of view and the values are fitted to a two dimensional, third order polynomial. The image is corrected by resampling the original pixels based on this polynomial. The undistorted pixel positions (X_u, Y_u) are calculated as follows:

$$X_u = \sum_{i,j} kx_{i,j} \cdot X_0^i \cdot Y_0^j$$

$$Y_u = \sum_{i,j} ky_{i,j} \cdot X_0^i \cdot Y_0^j$$

Here, the undistorted coordinates (X_u, Y_u) are expressed as a function of the actual image coordinates (X_0, Y_0). The coefficients for distortion removal (kx and ky) are the coefficients of the third-order polynomial fit. To obtain the corrected level 3 images, the level 2 images are wrapped according to the kx and ky distortion removal coefficients.

2.2 Correction parameters

The distortion correction parameters were derived during the ground calibration and the first in-flight calibration sequences. The current NAC parameters were obtained by fitting the original PDS float image format on 2014-10-20. The fitting error was less than 0.1 pixels over the full field of view. The parameters are listed in listed in Table 1.

Table 1: Coefficients for geometric distortion removal.

index		NAC		WAC	
i	j	kx	ky	kx	ky
0	0	-9.09076000E+00	4.61801000E+00	7.78487000E+01	-1.97971000E+01
0	1	9.06443000E-04	9.97063000E-01	-4.17323000E-02	1.01229000E+00
0	2	-5.26902000E-07	-5.93490000E-07	2.22691000E-05	1.41482000E-05
0	3	-3.32516000E-12	1.99967000E-10	-1.21773000E-17	-5.03314000E-09
1	0	1.01413000E+00	3.21866000E-03	9.10810000E-01	-1.03768000E-02
1	1	-2.39320000E-07	-3.38901000E-06	7.76574000E-06	1.08393000E-05
1	2	1.19823000E-10	1.88602000E-12	-4.14394000E-09	3.76481000E-10
1	3	-2.01772000E-16	-1.95971000E-17	4.93332000E-20	-1.33931000E-13
2	0	-4.71201000E-06	-6.41550000E-08	3.32148000E-05	4.87161000E-06
2	1	8.98608000E-12	1.16434000E-10	8.75255000E-10	-5.06338000E-09
2	2	-7.17827000E-16	-1.12755000E-16	-4.67052000E-13	-2.17359000E-13
2	3	2.23917000E-19	3.01745000E-20	-4.67452000E-23	7.73245000E-17
3	0	2.91214000E-10	-1.06652000E-11	-4.88078000E-09	-1.77868000E-11
3	1	-1.94627000E-16	-4.15382000E-17	-1.39050000E-13	1.73440000E-14
3	2	2.20615000E-19	3.98303000E-20	7.41997000E-17	2.62340000E-18
3	3	-6.87882000E-23	-1.09102000E-23	1.40179000E-26	-9.33268000E-22

3 Parameter validation

The camera distortion parameters were validated by in-flight calibration imaging sequences, and star position fitting. The calculations used the following images (Table 2), and the Tycho2 star catalogue astrometric data.

Table 2: Images used for validation.

No	Image ID	Activity Name
1	NAC_2014-03-24T03.07.57.548Z_ID30_1251276900_F22	STP001_ONIT_1
2	NAC_2014-05-11T03.46.11.207Z_ID30_1397549000_F22	STP003_CALIB_FIELD_NAC
3	NAC_2014-05-11T03.44.48.561Z_ID30_1397549000_F24	STP003_CALIB_FIELD_NAC
4	NAC_2014-06-01T11.20.54.559Z_ID30_1397549900_F22	STP004_ONIT_021
5	WAC_2014-03-20T01.14.53.738Z_ID30_1251276000_F12	STP001_WAC_Commissioning
6	WAC_2014-05-11T06.01.55.412Z_ID30_1397549000_F21	STP003_CALIB_FIELD_WAC
7	WAC_2015-09-11T15.10.52.843Z_ID30_1397549000_F12	STP073_GRAIN_TRACK_003

3.1 Calculation method

- The average (A_{pix}) and the standard deviation (S_{pix}) of the pixel intensities were calculated for the full area of the distortion corrected calibrated images (level 3).
- The image area was scanned for high intensity, small size, and symmetrical artefacts.
- 2D Gaussian fit was applied on the 15x15 pixel area surrounding the highest intensity pixel of the artefact for point spread function (PSF) estimation.
- If the standard deviation parameter of the fit in both direction was < 2.2 and the maximum intensity was > ($A_{pix}+3S_{pix}$), the artefact was considered a star and the parameters were recorded.
- Star positions of the imaged field of view were extracted from the catalogue, corrected for proper motion.
- The angular positions were projected onto the camera image plane by gnomonic projection using the camera parameters.
- The matching star and detected PSF positions were paired. Detected star positions with no matching catalog stars were ignored (possible noise, cosmics, etc).
- The camera pointing parameters (Right Ascension, Declination, north azimuth and camera focus) were optimized to result the smallest deviation of the positions.
- The average and the maximum of the position errors were calculated.

3.2 Validation results

The result of the validation is summarized in Table 3. Approximately 72-231 stars were detected per image, being evenly distributed over the field of view. An outcome of the star fitting is the PSF, which 1-sigma value from a Gaussian fit was found to be approx. ±1.0 pixel for both cameras. This is slightly larger than described in the OSIRIS ground calibration [RD1].

The focal length is treated as a free parameter in this validation and perfectly matches the focal length the distortion correction was set to. The design values for the distortion corrected level 3 products are 717.322 mm for the NAC (L. Jorda, pers. comm.) and 135.68 mm for the WAC (V.

Da Deppo, pers. comm.). This is consistent with the information in the OSIRIS instrument kernels of the Rosetta Spice set (ROS_OSIRIS_V14.TI and later).

The remaining distortion-correction errors are below 0.6 pixels for the NAC and 2.0 pixels for the WAC. Typical errors for the NAC are below 0.2 pixels (Figure 1), whis is much smaller than the PSF (~1 pixel) described above. The WAC is mostly below one pixel but has remaining distortions of ~2 pixels in two corners (Figure 2). It should be noted that the displayed colours in Figure 1 and Figure 2 represent *absolute numbers* of known *directed errors*.

Table 3: Star map fit results of selected images. The image number in the first column relates to Table 1.

No	Camera	Number of Stars	Error		Calculated pointing			
			Maximum [pix]	Average [pix]	Right Ascension [°]	Declination [°]	Celestial North [°]	Focal Length [mm]
1	NAC	109	0.57	0.13	4.3255	-0.2311	2.1439	717.28
2	NAC	82	0.63	0.16	4.3431	-0.2444	5.2378	717.32
3	NAC	72	0.64	0.17	4.3431	-0.2444	5.2379	717.31
4	NAC	108	0.57	0.13	4.3665	-0.2745	5.1932	717.29
5	WAC	198	1.99	0.72	4.3197	-0.2283	5.2849	135.68
6	WAC	231	2.01	0.63	4.3369	-0.2415	5.2336	135.70
7	WAC	182	1.92	0.61	82.2933	-0.8915	258.269	135.65

4 Calibration files used by OsiCalliope

The calibration files used by OsiCalliope [RD2] to calibrate OSIRIS images are:

- NAC_FM_DISTORTION_V01.TXT
- WAC_FM_DISTORTION_V01.TXT

Previous versions:

- NAC_FM_DISTORTION.LBL (obsolete, same values as NAC_FM_DISTORTION_V01.TXT)
- WAC_FM_DISTORTION.LBL (obsolete, same values as WAC_FM_DISTORTION_V01.TXT)
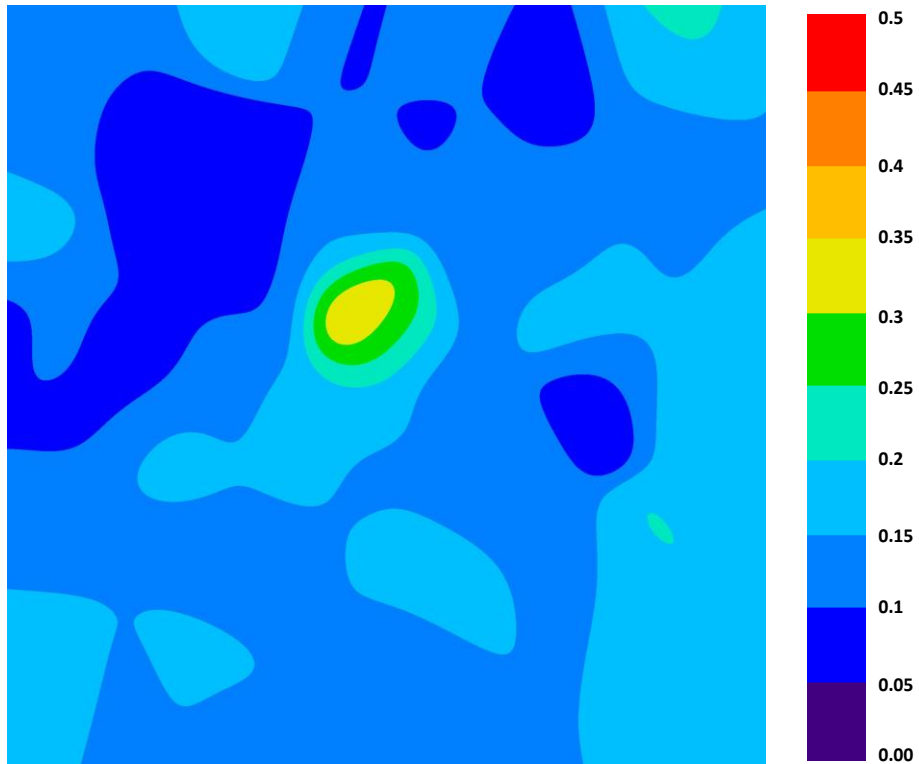
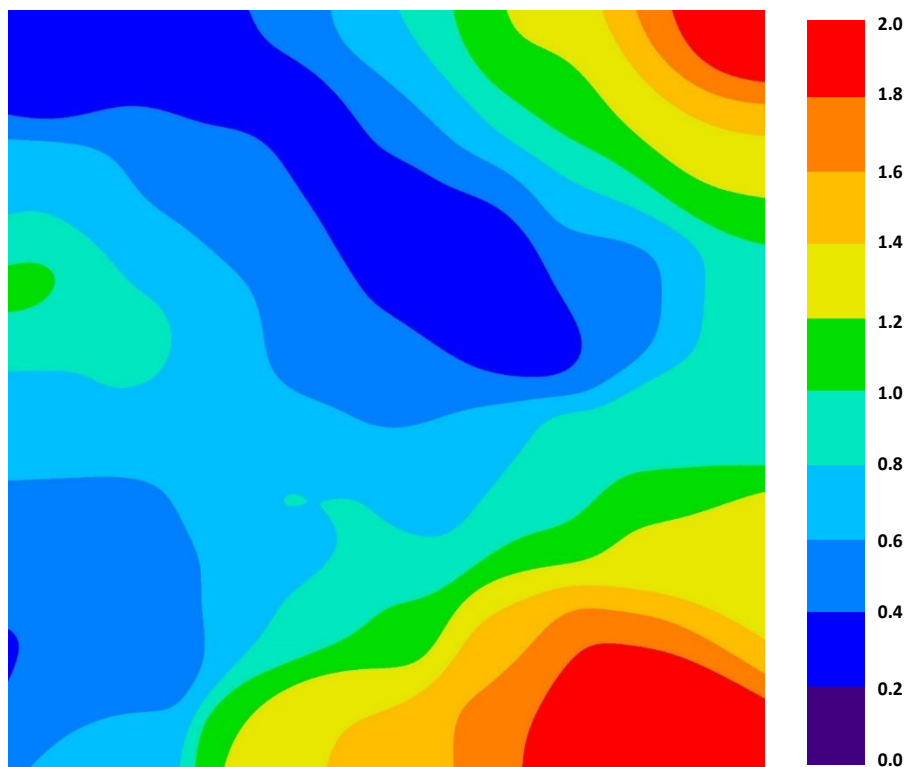**Figure 1:** NAC distortion correction error (0, 0 pix bottom left)

Figure 2: WAC distortion correction error (0, 0 pix bottom right)