GEOMETRIC GROUND CONTROL OF VERY HIGH RESOLUTION IMAGERY USING HRSC INTERSECTION POINTS AND A NON-RIGOROUS CAMERA MODEL JR. Kim[1] , J-P Muller, M.Balme and J. B. Murray[2], [1] Mullard Space Science Laboratory, Dept. of Space and Climate Physics, University College London, Holmbury St. Mary, Dorking, Surrey RH6 5NT, jk2@mssl.ucl.ac.uk, [2] Dept. of Earth Sciences, The Open University, Milton Keynes MK7 6AA.

Introduction: One of the most important issues in the mapping of Mars is the establishment of a sufficiently accurate geodetic control network on Mars. This is particularly now the case, with high resolution optical sensors such as MOC-NA and HiRISE, as reliable geodetic control at up to a few metres and in the near-term future sub-meter Mars imagery assumes the highest priority. In addition, extending traditional rigorous camera models has been a significant barrier to produce reliable extra-terrestrial-mapping products because the spacecraft tracking information to extract physical sensor parameters is not sufficiently accurate for the purpose.

Our approach is to address both problems using non-rigorous sensor modelling. A HRSC - MOC-NA matching scheme has been developed which uses SPICE kernel information together with conjugate tie points as the GCPs for the establishment of a non-rigorous camera model.

Implemetation: We tested two approaches for non-rigorous sensor modelling with MOC-NA imagery. One used affine transformation [1] and the other a terrain independent RPC (Rational Polynomial Coefficients) [2] and it's update [3]. In each case, the transformation parameters are extracted from matched HRSC intersection points (for affine transformation) or with the SPICE CK kernel (for RPCs).

If the GCP acquisition for an affine transformation is provided interactively, such non-rigorous modelling is not practicable or achievable. An automated processing routine which employ HRSC data sets, including level 3 optical images (i.e. georeferenced ortho-image using a MOLA DTM and bundle adjusted exterior orientation), and the 3D object point file produced from the space intersection routine as part of the so-called DLR-VICAR suite, was established. Using approximate tie points (a minimum of 3) between MOC-NA and HRSC images, a sub-section of HSRC which corresponds to the target MOC-NA image, is extracted. Then any highly sloped areas or poor quality intersection points are masked off. To produce uniformly distributed GCPs, the image surface is divided into equal sized tiles. In each image subsection, one preliminary GCP is randomly chosen. The image chip around such GCPs is matched with an ISIS (Integrated Software for Imagers and Spectrometers, http://wwwflag.wr.usgs.gov/ISIS/) formatted level 2 MOC-NA image. Around such estimated matched points, the ALSC (adaptive least squared correlation) image matcher [4] is applied. Then finally the GCPs which have image column and row co-ordinates in the level 1 MOC-NA image space and ground coordinates can be established. In addition, check points can also be derived with the same processor. For these GCPs, a least squares fitting process to extract affine transformation parameters is applied. The accuracy of the affine transformation is evaluated with check points. If the positional accuracy is lower than some critical value, the GCP setting process is repeated until a sufficiently accurate enough positioning can be established. The structure of the RPC processor consist of two sub-program – the RPC generator and RPC updating part.

The starting point for the terrain independent RPC generator is the collinearity equations which are shown in equation (1).

$$\begin{bmatrix} 0 \\ y \\ -f \end{bmatrix} = \lambda(R_\phi, R_\omega, R_\kappa) \begin{bmatrix} X - X_{oi} \\ Y - Y_{oi} \\ Z - Z_{oi} \end{bmatrix} \quad (1)$$

where X,Y,Z are the ground coordinates, X_{oi},Y_{oi},Z_{oi} are the coordinates of the projection center, λ is a scale parameter, f is the principal distance of the camera optics. Y is the image coordinate and R_ϕ R_ω R_κ are rotational matrixes.

Parameters such as rotational angle rotational matrixes $_{ij}$ and projection centre (Xo, Yo, Zo) can be extracted from the SPICE CK, SPK and IK kernel. We extracted m_{ij} and (Xo, Yo, Zo) along the MOC-NA image line number using these ISIS functions. A corresponding 3D object grid in latitude, longitude range of the MOC level-1 images and estimated highest range are established using level 1geoplane program in the ISIS MOC processing kit. With each grid point coordinate (X,Y,Z), the collinearity function is applied and can then be extracted and projected into image space considering the interior orientation of the MOC-NA sensor using the ISIS MOC processing function. Then using such pseudo GCPs, a RPC can be fitted. The detailed process of RPC fitting was explained in [2].

Such sets of RPCs is not sufficiently accurate at present because the base physical sensor information from SPICE is not sufficiently well calibrated. Therefore, there are lots of positional errors compared with the bundle block adjusted HRSC images. To correct this, we developed a RPC updating routine, recycling a portion of the GCP setting program in the affine processor. At first, using the initial RPC and level-1 images, a preliminary orthoimage on the Mars ellipse can be created. For consistency, the HRSC level 2 image can also be projected onto the Mars ellipse. These two images can then be matched using approximate tie points and the in-house ALSC image matcher can then be applied for the affine transformation part. The information extracted from such processing can be considered as the "true" ground coordinates by bundle blocked adjusted HRSC positioning information and the ground coordinate by an approximate predicted SPICE kernel. Therefore, the column and row shifts to update RPCs can be semi-automatically extracted.

The accuracy assessment of the affine transformation results is given in Table 1 and the corresponding evaluation of positional accuracy based on RPCs at various polynomial order are given in Table 2. From these experiments it appears that the positional accuracy of the RPCs is sufficient to produce a MOC-NA mosaic. Mosaic image examples using updated RPCs are shown in Figure 1.

	M0702284	M2301492	M0200340	R0300675
Case1	RMSx:0.36	1.93	1.39	4.18
	RMSy:0.56	1.92	1.18	3.78
	Stdx:1.24	3.36	2.35	5.23
	Stdy: 0.94	3.54	1.95	4.82
	Maxx:5.14	11.41	8.24	12.01
	Maxy:4.31	12.37	7.71	17.36
Case2	0.69	0.81	0.91	0.76
	0.58	1.06	0.81	0.68
	1.04	1.32	1.46	1.29
	0.87	1.60	1.32	1.14
	4.28	4.95	5.29	5.98
	3.53	5.65	6.43	5.74

Table 1. Results from the accuracy assessment of the affine transformation variants for MOC image e0502918 (unit pixel, case1 : Affine with the coordinates in a sinusoidal projection; case2 : Affine with error compensation term)

	M0702284	M2301492	M0200340	R0300675
2nd order RPC	RMSx:1.40	1.29	0.67	0.33
	RMSy:0.44	0.94	1.10	1.92
	Stdx:1.65	1.62	1.31	0.40
	Stdy:0.54	1.49	2.17	0.41
	Maxx:2.17	4.24	2.06	0.95
	Maxy:1.08	4.15	2.18	2.75
3rd order RPC	0.58	1.12	0.86	1.52
	0.41	1.23	1.49	2.07
	0.69	1.40	0.65	2.42
	0.47	1.61	0.56	1.42
	5.24	5.45	2.10	2.64
	2.22	6.83	2.30	2.65

Table 2. The accuracy assessment for different RPC orders (unit : pixel)

DTM extraction using both sensor models is not yet sufficiently accurate in most cases studied to date. In some image pairs such as the MOC-NA stereo pair m0200340s and r0300675, a rough DTM could be extracted. However, it should be noted such successful intersection using the non-rigorous model is still very rare. More sophisticated non-rigorous models are currently under which have been successfully applied to a large variety of different types of EO imagery. This method offers the possibility of being able to create stereo intersection geometry as well as planimetrically co-registered datasets over the full range of resolutions from HiRise to Viking Orbiter using the unique geometric properties of the HRSC, suitably bundle-block adjusted with the MOLA tracks.

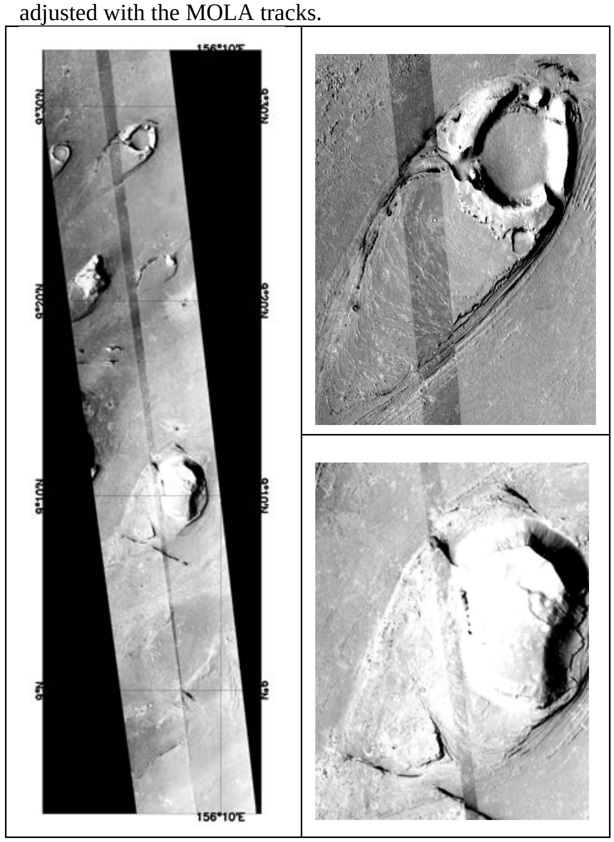

Figure 1 MOC-NA image mosaic using RPCs using 3 MOC-NA images (m2301492, r0300675 and e0503124)

Conclusions: In this study, we have shown a semi-automated non-rigorous sensor model fitting method using MOC-NA image and HRSC intersection points and assessed the accuracy of derived ortho-image products.

Both affine and RPC approaches showed good reliability to produce sufficiently accurate ortho-images data sets with minimal manual input. In particular it appears that, 2nd order RPC produced the best result.

All the methods developed in this study might be useful for partial ortho-image generation without any photogrammetric tool and sensor parameters. In the near future, we plan to develop new solutions to address the stereo intersection problem and extend the usage of non-rigorous modelling to 3D mapping product generation.

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