AN AUTOMATED DIGITAL APPROACH FOR THE GENERATION OF DIGITAL TERRAIN MODELS USING HRSC AND WAOSS IMAGE DATA OF THE MARS96 MISSION

Robert Uebbing
Technical University of Berlin, Department for Photogrammetry and Cartography
Sekr. EB9, Straße d. 17. Juni 135, D-10623 Berlin, Germany
Tel.: +49-30-314-23991, Fax: +49-30-314--21104, E-mail: robert@fpk.tu-berlin.de

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ABSTRACT:

The Russian Mars96 Mission is going to be launched in autumn 1996. It will carry the German cameras HRSC (High Resolution Stereo Camera) and WAOSS (Wide Angle Optoelectronic Stereo Scanner). This combined experiment will provide multiple along-track stereo imagery of the whole planet Mars. Digital Terrain Models (DTMs) and derived products will be generated in a completely automated process. For the generation of DTMs accurate orientation data of the sensor is essential. Furthermore a multi-image matching process must be utilized and a reference body must be defined. Standard ray intersections with a least-square adjustment is applied to compute a dense cloud of object points. Blunt errors are recognized with data-snooping algorithms and eliminated automatically. The points are then transformed onto the reference body, in this case a triaxial ellipsoid, with the help of standard geodetic transformations. Dependent on the image quality and therefore the quality of the matching process gaps may exist in the DTM. These must be closed with adequate interpolation methods. If the gaps exceed a certain size the height information for this area must be obtained through other techniques (e.g. shape from shading). The DTM is stored in an image with a data depth of 16 bit. This image can therefore represent a maximum height difference of 65 km with an accuracy of 1m. The DTM image is the basis not only for topographical maps and orthoimage mosaics but also for products like perspective views, contour maps, fly-bys and others.

KURZFASSUNG:

Die russische Mission Mars96 wird im Herbst 1996 gestartet. An Bord werden die Deutschen Kameras HRSC (High Resolution Stereo Camera) and WAOSS (Wide Angle Optoelectronic Stereo Scanner) sein. Der gesamte Planet Mars wird von vielen Stereoaufnahmen, die in dem kombinierten Kameraexperiment aufgezeichnet werden, abgedeckt. Digitale Geländemodelle (DTM) und weitere Erzeugnisse werden von den Bilddaten in einem vollständig automatisierten Prozeß abgeleitet. Für die Erzeugung von DTMs sind hochgenaue Orientierungsdaten notwendig. Außerdem muß eine Korrelation durchgeführt werden und ein Körper definiert werden, auf den das DTM bezogen wird. Geradenschnitte mit einer Ausgleichung nach der Methode der kleinsten Quadrate werden durchgeführt, um eine dichte Wolke von Objektpunkten zu berechnen. Grobe Fehler werden automatisch mit Hilfe von Data-Snooping-Algorithmen erkannt und sofort beseitigt. Mit Hilfe von geodätischen Standardtransformationen werden die Punkte dann auf den Referenzkörper, in diesem Falle ein dreiachsiges Ellipsoid, abgebildet. Je nach Bildqualität und dementsprechend auch der Qualität der Korrelation können Lücken im DTM vorhanden sein. Diese müssen mit entsprechenden Interpolationsmethoden geschlossen werden. Falls jedoch die Lücken eine bestimmte Größe überschreiten, müssen andere Techniken angewandt werden, um sie zu schließen (z.B. Shape-from-shading-Verfahren). Das DTM wird in Form einer Bilddatei mit einer Farbtiefe von 16 bit gespeichert. Folglich kann das DTM einen Höhenbereich von 65 km bei einer Genauigkeit von 1m darstellen. Das DTM ist eine Grundlage nicht nur für topographische Karten und Orthobildmosaike sondern auch für weitere Produkte wie Perspektivansichten, Höhenlinienbilder, Vorbeiflüge und andere.

1. GENERAL ASPECTS OF DTM GENERATION FOR THE MARS MISSION

In the fall of 1996 a Russian spacecraft to planet Mars will be launched. On board its platform two cameras will be installed which are particularly designed for photogrammetric purposes. The WAOSS (Wide Angle Optoelectronic Stereo Scanner) and the HRSC (High Resolution Stereo Camera) will provide planetary image data from Mars. These images are going to be processed utilizing photogrammetric and other methods.

A complete photogrammetric/cartographic processing line including digital image matching, DTM generation, orthoimage generation, mosaicking, merging of multispectral data and cartographic processing for the production of Topographic Image Maps has been developed for the Mars96 Mission at the Technical University of Berlin, Department for Photogrammetry and Cartography (Prof. Dr.-Ing. J. Albertz) in cooperation with other Co-Investigators (Albertz et al. 1992).

The Digital Terrain Model (DTM) is the standard form of the discrete three-dimensional representation of terrains. The DTM generation belongs to one of the key issues in the chain of data processing. For many aspects of interpretation of the image data a DTM is required. Also for enhancing the accuracy of 2D products like orthoimages and orthoimage mosaics DTMs are essential. Finally derived products like contour maps, colour-coded height images and fly-by movies can be created with the help of DTMs. Because of the wide range of the expected spatial resolution of HRSC and WAOSS image data, a global DTM derived from WAOSS data is expected as well as local DTMs of high resolution using HRSC data.

First implementations of the photogrammetric software were tested with Clementine images of the Moon. Although the Clementine images are frame-grabber images, it was possible to simulate line scanner imagery similar to the ones from the HRSC and WAOSS camera.

The generation of a DTM requires roughly three steps. At first the object points in space must be calculated from image coordinates of conjugate points determined by the digital image matching processes, secondly the object points must be transformed into the desired map reference system, and finally a regular grid of height points has to be generated. For this method of generating DTMs, which is going to be implemented for the Mars96 Mission, the following input is necessary: results from the correlation of corresponding images and the orientation of the camera throughout the recording of the images. Furthermore a fixed reference body must be well defined. With this information a DTM of the area covered by the images can be computed.

2. COMPUTATION OF OBJECT POINTS

The input for the calculation of object points in space are the results of the matching process of two or more images. These results are discrete pixel positions of conjugating points in the images. Each pixel in the image data corresponds with a unique ray, which is well-defined through camera position and pointing, in space. Given this information for at least two pixel positions a point in space can be calculated through a standard ray intersection. Using more than two images an adequate least-square adjustment can be applied. This is very helpful for finding blunt errors in the foregoing correlation or in the navigation data as well.

At least two images are needed for the determination of conjugate points. But the HRSC/ WAOSS experiment with its nine (HRSC) and three (WAOSS) linear CCD arrays will provide multiple along-track stereo capability. Even conjugate points in cross-track overlapping can be introduced to the system. These results together with the pointing and position information of the camera for the corresponding image lines define rays in space. Due to the sensibility of the system towards the orientation of the camera, especially its pointing, the navigation parameters have to be recorded as accurate as possible and will be improved through a photogrammetric bundle block adjustment, which is the task of the Technical University of Munich, Chair for Photogrammetry and Remote Sensing (Prof. Dr.-Ing. H. Ebner). Besides the position and pointing accuracy the quality of the matching process also has influence on the definition of the object points.

The discrete object points can then be calculated through a standard ray intersection with a least-squares adjustment technique. Due to the possible number of involved images and the possible high matching resolution, the computation can be quite intensive. Utilizing least-squares adjustment for each single point, blunt errors can be detected and the affected points are eliminated.

The quality of the points depends on the following:

- quality of the navigation/orbit data
- quality of the correlation
- number of used images

The most important factor defining the quality scale is the navigation/orbit data.

The result of this calculation process is a dense cloud of irregularly distributed points in space.

3. TRANSFORMATION OF OBJECT POINTS ONTO PLANET SURFACE

In order to generate a regular grid of DTM data the calculated cluster of points in object space must first be transformed into a geographical system using a reference ellipsoid. Herefore a standard geodetic transformation is utilized. The position and the height of each point can be calculated referring to different ellipsoids. While planimetry will be defined on an oblate spheroid the basic height reference system for the planet Mars is a triaxial ellipsoid. Thereafter the points are transformed into a given map projection which defines a rectangular line and sample coordinate system. However, they still form an irregular grid.

4. INTERPOLATION OF A REGULAR GRID

From the irregular grid of map projected object points a regular grid has to be derived by means of adequate interpolation methods. The following methods are implemented in the software system: nearest neighbour, sector based interpolation, sector based weighted average interpolation (Fig.1) and criging.

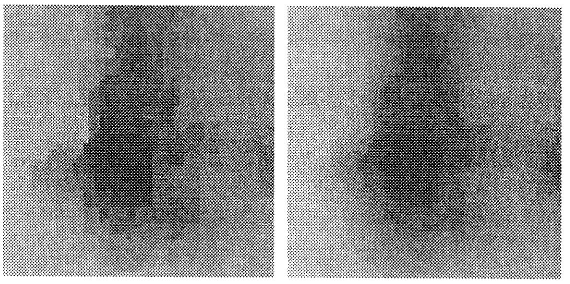

Figure 1: Effects of interpolation (gray values = heights).
Left: interpolation using nearest neighbor.
Right: interpolation by a sector based weighted approach

As a result of the interpolation the DTM grid is represented by an image where line and sample of a pixel define the planimetry in the map projection. The height above the reference body is coded as a grey value with a depth of 16 bits. With this type of integer data it is possible to describe 65,536 different heights. Considering that a height accuracy of 1 meter or better cannot be expected due to image resolution and the accuracy of the recorded orientation parameters, each grey value represents a fixed height in steps of 1 meter. Thus the 16bit-depth of the data includes the entire range of possible heights on Mars with its tremendous height differences rising up to 30 kilometers.

Figure 2: Visualization of a DTM as 8 bit grey value coded image

For the visualization of the resulting grey-level coded height image it is necessary to compress the 16 bit grey values to 8 bit grey values (Fig.2). Various other types of visualization techniques of DTM information will also be developed under the software and hardware guidelines of the Mars96 Mission, e.g. contour lines (Fig.4), wire frames or perspective views (Fig.3) of a DTM probably overlayed with image information.

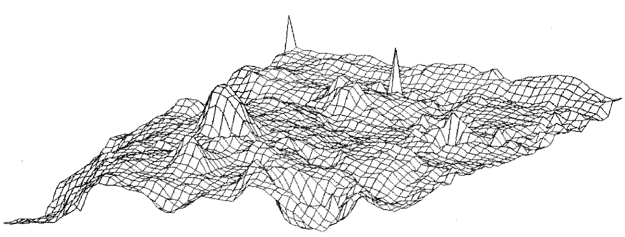

Figure 3: Perspective view derived from the DTM shown in Fig.2

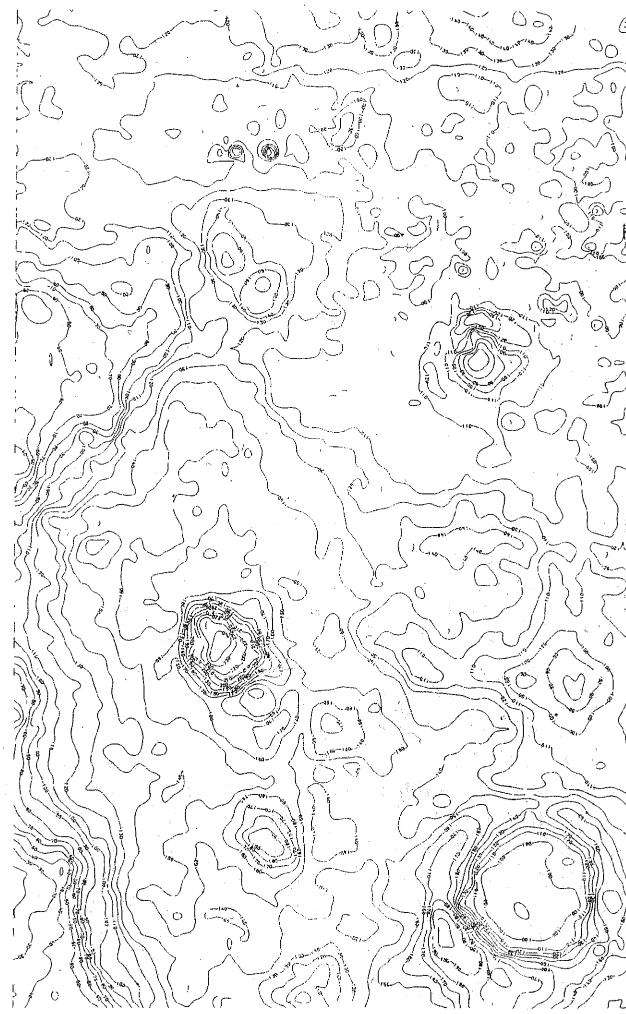

Figure 4: Contour map derived from the DTM shown in Fig.2

5. CONCLUSIONS

The developed techniques for the generation of Digital Terrain Models are, together with components for image matching, orthoimage and image mosaic generation and automated cartographic software, essential parts of an overall processing line for the production of Topographic Image Maps during the Mars 96 Mission (Albertz et al 1996). Beside this, the developed approach for DTM generation can be applied to any modeling of heights where a high density of object points exist. The quality of the products always depend on the accuracy of the geometrical processing.

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