AUTOMATED GENERATION OF COLOURED ORTHOIMAGES AND IMAGE MOSAICS USING HRSC AND WAOSS IMAGE DATA OF THE MARS96 MISSION

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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. Orthoimages and coloured image mosaics will be generated in completely automated processes. Orthoimage generation uses geometric calibration information of the CCD line scanners HRSC and WAOSS, orbit and pointing information for each line of the entire strip of image data (improved by photogrammetric bundle adjustment) and Digital Terrain Models (DTMs) derived by multi-image matching and special interpolation techniques. While the geometrical aspect of mosaicking will be taken care of within the bundle block adjustment radiometrical mosaicking has been improved in that way, that all definitions which had to be made in advance, e.g. definition of overlapping regions and division lines, are now performed automatically and not interactively on the screen of an image processing system. High quality coloured mosaics can be generated afterwards using IHS colour transformation in order to preserve high resolution as well as colour information. Especially true colour Topographic Image Maps in scales 1:500,000 up to 1:50,000, containing contour lines derived from a DTM, are the desired products of this cartography-oriented mission to planet Mars.

1. GENERAL ASPECTS OF HRSC AND WAOSS IMAGE DATA

The HRSC and WAOSS cameras (Albertz et al., 1992) are very special line scanners the commanding strategies of which allow different types of imaging sequences of inhomogeneous structure. Thus the beginning of image lines may start at varying sample positions of the imaging CCD array within one data set, may have a varying number of samples per line, and even gaps between image lines may appear due to possible loss of data during transmission or decompression. Furthermore the scale of a pixel will not be constant within one data set because of the extreme elliptical orbit of the spacecraft. The scale factor may vary within one imaging sequence by the factor of approximately 10. Other commanding strategies will also form so-called macropixels by combining $2 \cdot 2$ or up to $31 \cdot 31$ pixels to one macropixel in order to generate a nearly constant resolution on ground. Last but not least the commanded time intervals between the lines will not be constant due the elliptical orbit.

These powerful commanding strategies offer an enormous variability of imaging sequences in order to optimize data acquisition to the orbit geometry and the scientific requirements. On the other hand traditional image processing techniques have to be adapted and improved in order to enable operational and fully automated processing.

Fig. 1 shows part of the planet's surface as it is (a), imaged from an elliptical orbit with imaging distance varying by a factor of 2 (b), and imaged from the same orbit with macropixel formats varying from 5 to 10 (c).

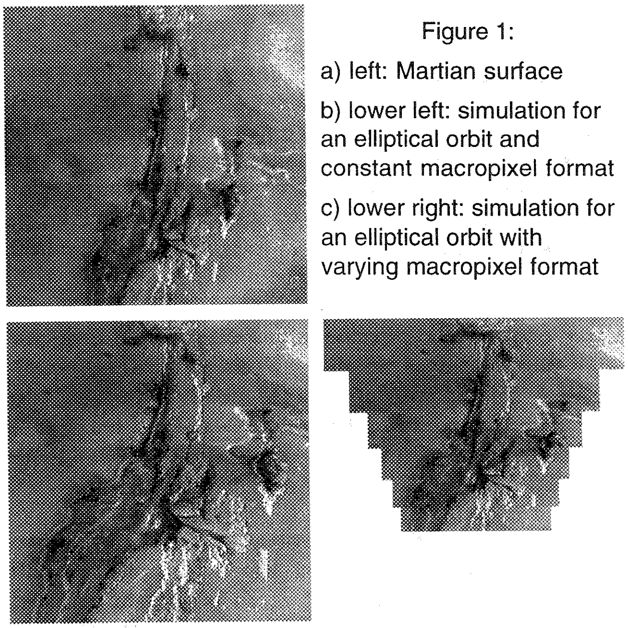

Figure 1:

a) left: Martian surface

b) lower left: simulation for an elliptical orbit and constant macropixel format

c) lower right: simulation for an elliptical orbit with varying macropixel format

With respect to mapping purposes HRSC and WAOSS on such an elliptical orbit will provide imagery for large scale topographic image maps in scales up to 1:50,000 as well as global views of the planet from limb to limb, appropriate for smaller map scales.

This is also a challenge for automated mapping software because of the great variety of different map projections with their sometimes critical behaviour in such extreme geometric constellations.

2. GENERATION OF ORTHOIMAGES

In general line scanner imagery has its own variable absolute orientation for each scan line. This is significant especially if airborne scanner imagery is processed (Zhang et al., 1994). In this case parametric rectification methods using the measured absolute orientation has to be applied. Non-parametric rectification where three-dimensional ground control points are used to decribe the continuous orientation can only be applied to imaging line scanners of spaceborne missions like SPOT (Albertz et al., 1990). Within these approximately circular orbits the sensor orientation does not contain high frequent and non-continuous variations of position and pointing. Planetary missions are mostly flown on elliptical orbits which can also be considered to be continuous but the varying observation distance does not allow the application of non-parametric approaches. Too many ground control information would be necessary, but such information is not available in sufficient quality and quantity for Mars and for most of the other planets.

Therefore and because of the decribed technical capabilities of both cameras orthoimages of HRSC and WAOSS data will be derived using a combination of parametric and non-parametric approaches (Fig. 2). Grid points defining a patch pattern within the image are projected to the surface using the absolute orientation while all positions within the patches are described by projective transformation using the patch edges as identical points (anchor points).

The patchwise transformation of image data of HRSC and WAOSS is based on the assumption that position and pointing of the sensor varies continuously within shorter periods. The length of these periods can be expected in the range of up to 50 lines while changes within the sensor commanding might appear in a frequence of up to 8 lines, thus adequate patch sizes seem to be between 8 and 50 pixels.

Proper position and pointing information will be acquired during the mission in form of so called SPICE kernels (including also information about planetary constants and instrument parameters). The orientation data will be improved by photogrammetric bundle block adjustment (Ohlhof, 1996).

A ray tracing algorithm (Jahn et al., 1992) is applied to compute the intersection of the line of sight vector with the surface given by the DTM which is defined above a triaxial ellipsoid as the height reference body. Patches will be rectified if the DTM (Uebbing, 1996, Wewel, 1996) contains reliable height information for all patch edges.

The intersection points of the patch edges will then be transformed to a given map projection defining not only the projection type but also the scale of the final orthoimage. All pixel positions within the map projected patches will then be transformed back (indirect rectification) to the patch in the input image using projective transformation with the patch edges as identical points. This process assumes that surface variations within these patches can be regarded to be constant. However, if the terrain information, given by the DTM, shows higher frequencies the patch size has to be decreased, if necessary up to a size of 1 pixel.

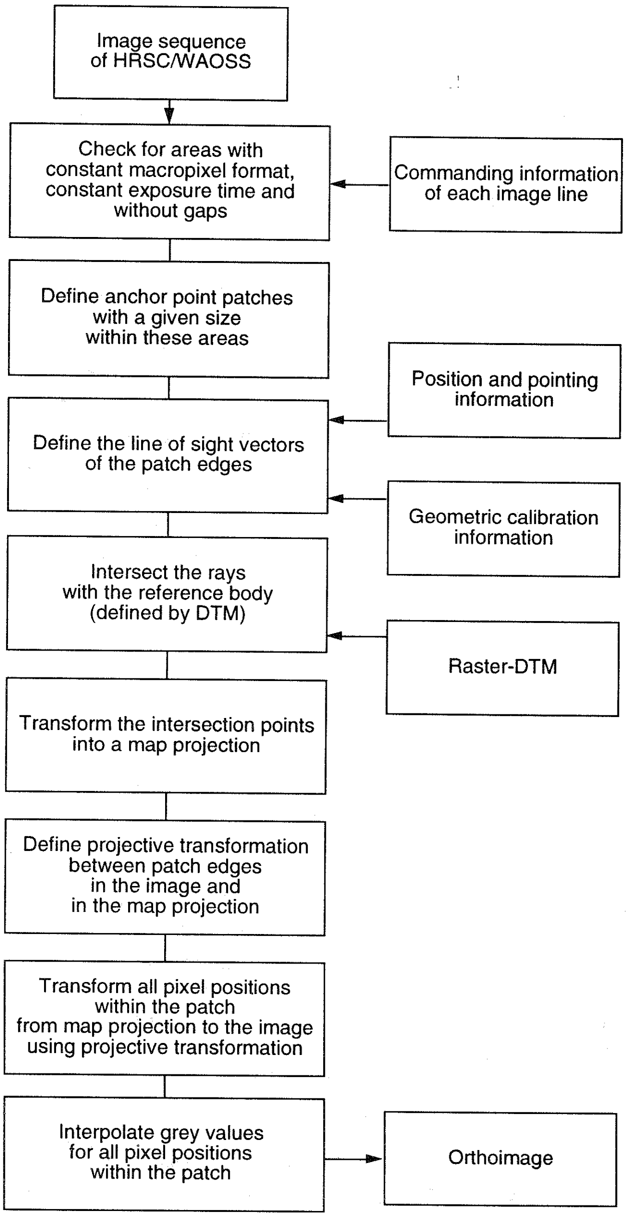

Figure 2: Orthoimage generation of HRSC/WAOSS data

In addition to this some map projection types describe distortions with respect to the surface which do not allow the application of projective transformation in large patches. In these cases patch sizes larger than 5 again are not appropriate.

As an example for such an extreme map projection Fig. 3a shows an image acquired during the GALILEO mission from the north pole region of the Moon (partly in shadow), Fig. 3b displays this image map projected to the Sinusoidal projection where the pole is represented by a point. Fig. 3c shows the distortion of the input patches.

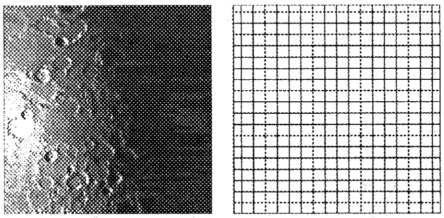

Figure 3a: left: GALILEO image; right: patch pattern

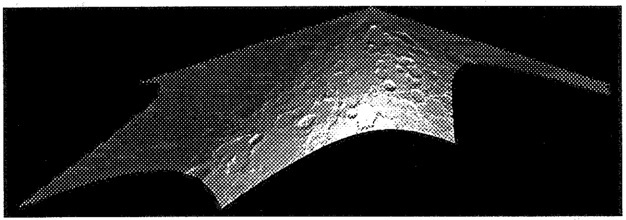

Figure 3b: Sinusoidal projected GALILEO image

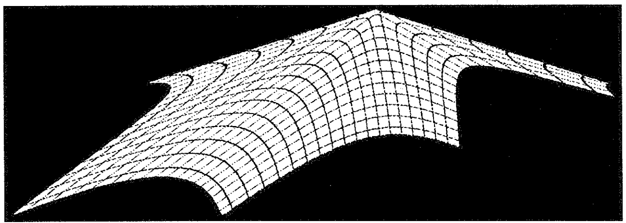

Figure 3c: Sinusoidal projected patch pattern

In order to derive the final output grey values for all positions within the patch common interpolation techniques (Nearest Neighbour, Bilinear Interpolation, Cubic Convolution) are used. With the knowledge of the incidence angle, the direction of observation and the direction of the local surface normal optional photometric correction can be applied to the interpolated grey values, thus introducing artifical illumination.

The result of this process applied to HRSC and WAOSS data is an orthoimage which can be used, e.g. for mosaicking purposes. This is necessary to yield rectified data sets for the generation of map sheets of one of the prospected map series to be produced within the Mars96 Mission (Lehmann, 1996).

Orthoimage production based on absolute orientation information was intensively tested on image data of the CLEMENTINE mission to the Moon (Fig. 4).

Figure 4a: Input image (CLEMENTINE mission)

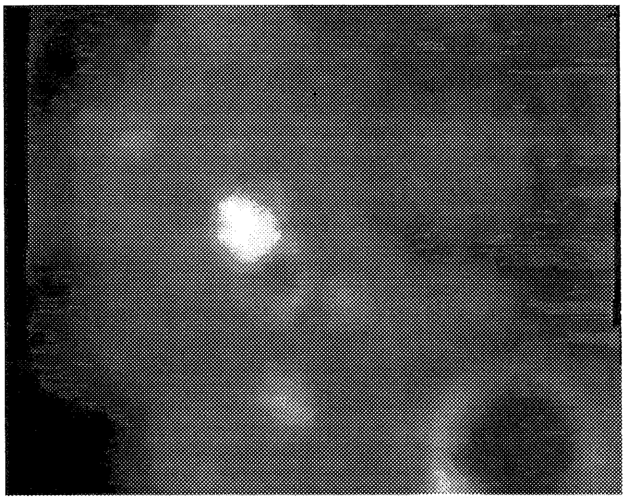

Figure 4b: Grey level coded DTM

Figure 4c: Orthoimage

3. GENERATION OF IMAGE MOSAICS

The generation of controlled image mosaics is a well known problem in image processing. During the Mars96 Mission parts of images acquired within one orbit as well as images of adjacent orbits have to be mosaicked in order to generate homogeneous data sets for large areas. The radiometrical mosaicking process uses geometrically corrected images (without using DTM information) or orthoimages as input. The geometrical mosaicking is performed within the photogrammetric bundle block adjustment where the absolute orientation of each image is optimized and can be regarded to be fixed. All informations which are necessary for the radiometrical mosaicking process are stored as label entries within each image (e.g. geometrical offsets).

Compared with former mosaicking software this new approach (Fig. 5) needs no further information or interactive input by an operator. Former definitions which had to be set manually like the definition of overlapping regions or the position of division lines are now derived automatically. This as well as modern standard hardware components with sufficient main memory enables mosaicking of a nearly unlimited number of input images without operator interaction.

The radiometrical mosaicking process consists of two main components, the adjustment of the grey values of the input images and the elimination of multiple information in the overlapping regions. Aspects of histogram adjustment are discussed by Kähler (1989). The solution described there, an integral histogram adjustment, has been tested in several satellite image mapping activities and was adapted to this approach.

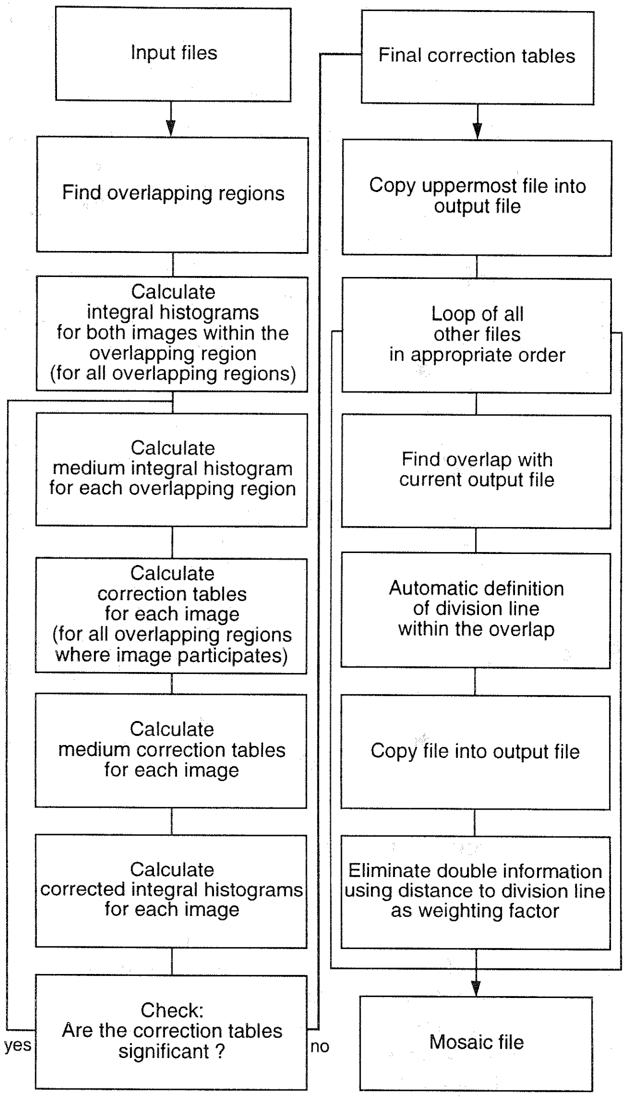

Figure 5: Scheme of radiometrical mosaicking approach

The elimination of multiple information is now done automatically. In spite of commonly processed data of the Earth (SPOT-HRV, Thematic Mapper or aerial photography) planetary image data show, when they are rectified to a map projection, complicated forms of the orthoimage boundary. This effect is due to changing observation distances as they appear on elliptical orbits within one imaging session, to the corresponding variable camera commanding or to the application of special map projections (Fig. 3). The results are very different shapes of the overlapping areas. While the automatic detection of the overlaps is unambiguous because of the given offsets of each image, it is more difficult to define for each position within the overlap how much information from each image (weighting factor) has to be used in order to generate the final mosaic file with a homogenous and breakless transition from one image to another. This is achieved using relations to the division line of the overlap. At first the points A and B, start and end point of the division line and defining its general direction, have to be found. Then the division line is defined as the connection of all local centers defined normal to the division line (Fig. 6). For a point P in the image mosaic the grey value gv_P is calculated by

$$gv_P = gv_n \cdot p_n + gv_f \cdot p_f$$

The weight p_n for the grey value gv_n of the nearer image is

$$p_n = 1.0 - 0.5 \cdot (d_1/d_2)^2 \text{ and } p_f = 1.0 - p_n$$

d_1 = Distance of P to border of farer image

d_2 = Dist. of overlap local center to border of farer image

For the definition of the "nearer" and the "farer" image, the positions of the center of each image are used. If an image is, relative to the division line which is defined from A to B, the *upper* image and P is *below* the local center of the overlap then, for P, the upper image is the "farer" one.

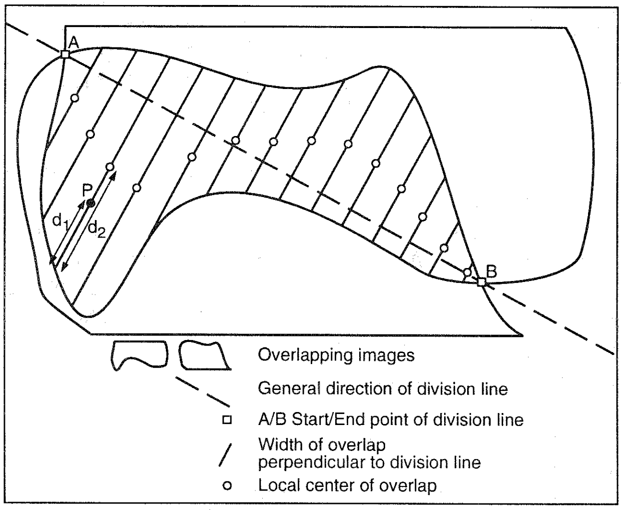

Figure 6: Definition of division lines

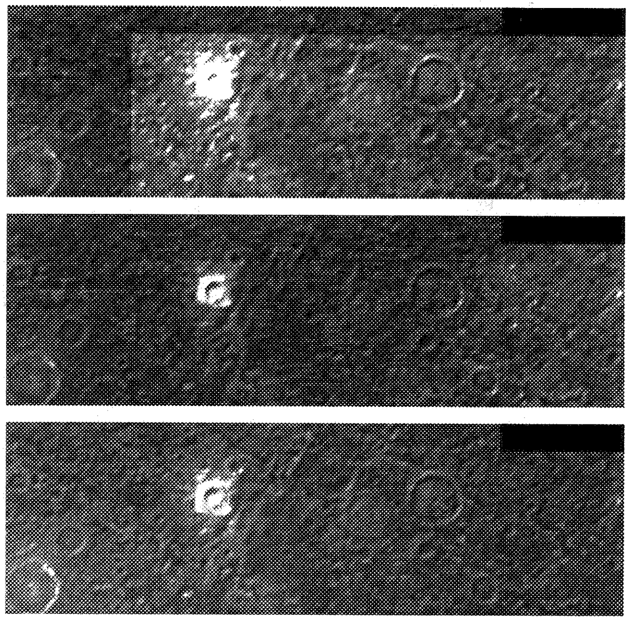

Figure 7: Different techniques of mosaicking

Fig. 7 (parts of VOYAGER images of Jupiters satellite Ganymede) shows the different mosaicking techniques (top: copying, middle: weighted elimination of double information, bottom: histogram adjustment and weighted elimination) while Fig. 8 demonstrates the capabilities of the approach even if the grey levels of the input files vary drastically.

The approach was tested on image mosaics of up to 3000 images. Fig. 9 shows a mosaic of 779 CLEMENTINE images of the Moon containing a few thousands of very different types of overlaps. The gaps are due to missing input images.

The overall capabilities of the mosaicking process are characterized not only by the quality of the final result but also the software performance. Besides the entire automation and the robust behaviour on nearly any kind of overlapping scenario, the computation time is reduced from days or weeks to a few seconds. Even very large mosaics with thousands of images can be computed within few hours.

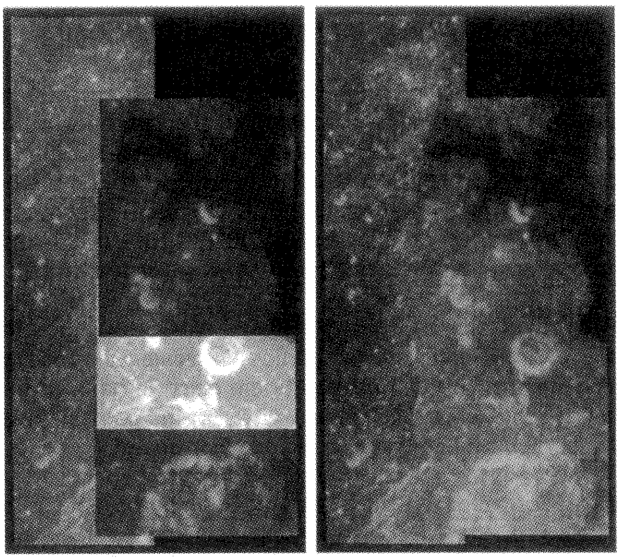

Figure 8: 11 CLEMENTINE images
left: images copied
right: mosaicked with integral histogram adjustment
and weighted elimination of double information

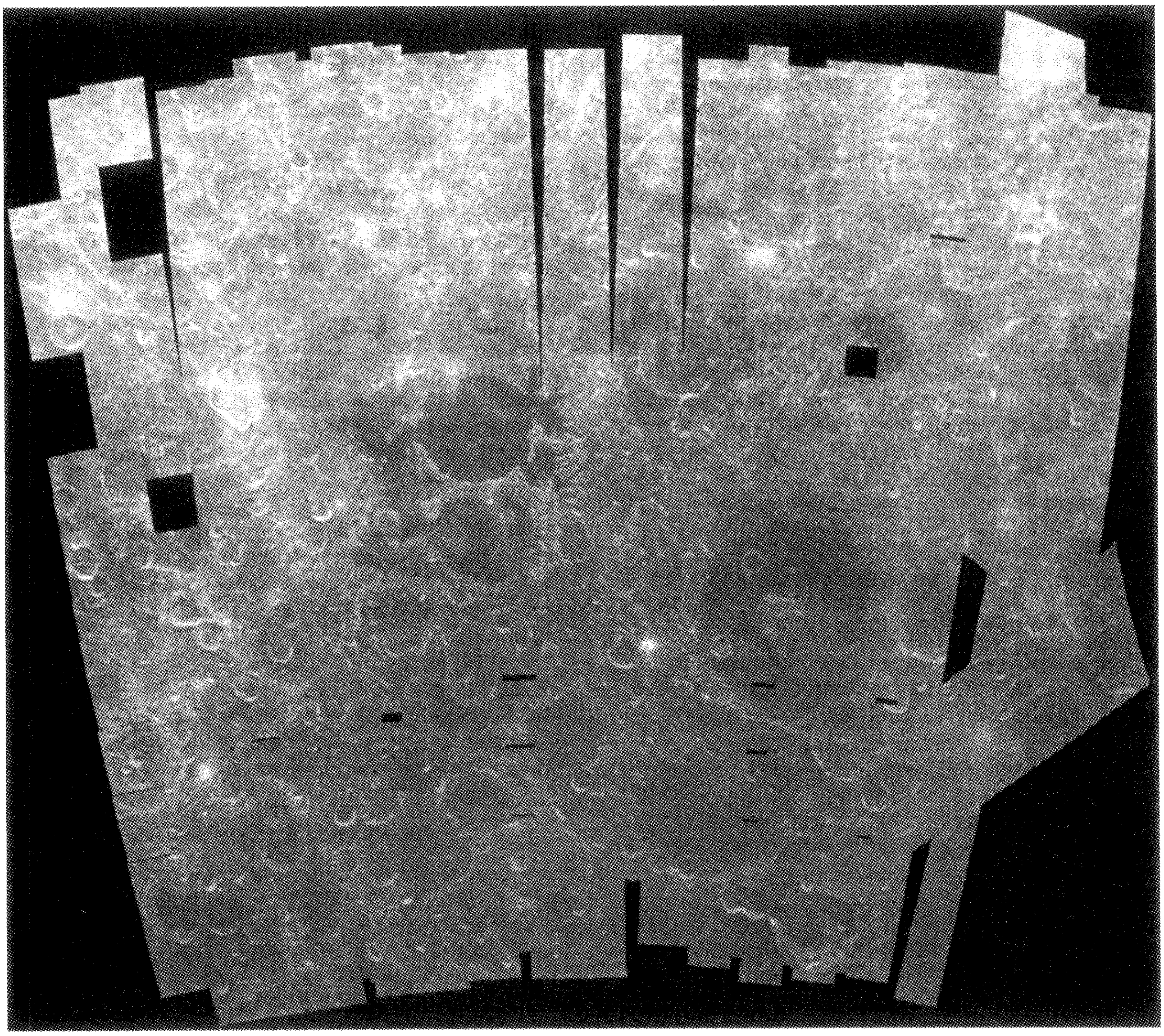

Figure 9: Mosaic of 779 CLEMENTINE images

4. GENERATION OF COLOURED MOSAICS

The generation of products (orthoimages and mosaics) in colour follows the same procedure as described before. If appropriate multispectral imagery is available and processed to equivalent geometry the single channels can be merged to one RGB file, but the selection and the radiometrical preparation of appropriate multispectral data for the actual task has to be performed carefully.

Within the Mars96 Mission HRSC and WAOSS will provide imagery with different properties in scale and colour (Albertz et al., 1992) These data are going to be used for geoscientific interpretation as well as for the generation of Topographic Image Maps in various map series.

While for geoscientific interpretation purposes three colours for the RGB file are often derived by the computation of colour ratios (Wählisch et al., 1996), image mapping often tries to yield true colour representation. Within the production of Topographic Image Maps during the Mars96 Mission the IHS colour transformation is going to be applied (Tauch et al., 1990). Studies have to be made in advance in order to check the capabilities of the original HRSC colour data and to derive guidelines for processing steps which are necessary to get the targeted colour representation. The permanent and unpredictable variations in scale within the prospected data as well as the possible lack of received image data enforces variable strategies in the production of colour products.

5. CONCLUSIONS

The techniques developed for orthoimage and mosaic generation are, together with components for multi-image matching, DTM generation and automated cartographic software, essential parts of an overall processing line for the production of Topographic Image Maps during the Mars96 Mission (Albertz et al., 1996). Besides, the developed mosaicking approach can be applied to any type of imagery. The quality of the products always depends on the accuracy of the geometrical processing.

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