GENERATING A TRUE-3D IMAGE MAP OF HIGH RELIEF TERRAIN USING LENTICULAR FOIL

Buchroithner, M.F., Wälder, O., Habermann, K. and König, B.

Dresden University of Technology, Institute for Cartography,
D-01062 Dresden, Germany. Fax: +49 351 463 37028.
E-mail: Manfred.Buchroithner@mailbox.tu-dresden.de

ABSTRACT

Following the conceptual idea "from 3D camera to 3D view", the production of a true-3D image map of the Granatspitz Massif in the Eastern Alps, near Austria's highest peak, Grossglockner (3794 m), is described. Imagery of this glaciated high-alpine area has been acquired by the German Aerospace Center (DLR) using the DLR-developed High Resolution Stereo Camera (HRSC). This three-line scanner delivers digital multi-spectral scanner data of highest quality in a fore, aft and nadir mode, thus offering a perfect data set for true 3D visualisation by the lenticular lens method. The excellent radiometric properties of the imagery proved ideal for a true-colour depiction of this high-relief terrain containing both clear water bodies and snow-covered glaciated peaks above 3000 m. The map scale has been determined to be 1:15.000, thus making optimum use of the HRSC data resolution and resulting in a map format of 51.5 cm x 71 cm. The projection is Gauss-Krueger. Due to the interlacing of the sub-millimetre strips of the stereo-mates and the resulting decomposition in x-direction the integration of well-designed and easily legible signatures and letterings represent a challenge. The paper describes the lenticular lens principle, the image map generation and, in particular, the actual cartographic work with different approaches for both signatures and lettering.

1. SCOPE

Based on unpublished studies carried out in the 1970ies and the 1980ies by Manfred Buchroithner, Dresden University of Technology, with probationers who were members of alpine climbing courses, it has to be stated, that roughly 60 % of all map users are not in the position to spontaneously derive information about the third dimension from topographic maps. This applies particularly to high-relief terrain. Based on the finding of these studies (which are still intended to be published in the near future) the prime author of this paper has been trying to develop methods which enable the map reader to spontaneously perceive the relief information with the unaided eyes, i.e. without the use of either anaglyph glasses, chromadepth glasses, or polarisation glasses.

In a first attempt a high mountain map based on a white-light transmission hologram (holo-stereogram) has been produced (1, 2, 3). However, it turned out that apart from the need of an illumination with coherent light, the production costs of such high quality holographic maps are exorbitant.

This led to the search of other, more appropriate and also cheaper methods for the generation of true 3D cartographic hard copies. Some years ago first attempts using the so-called lenticular foil approach have been carried out with quite some success. The positive echo caused by these first thumbnail specimens made us think of the generation of a larger format map of high-alpine terrain.

In preparation of the Mars Express (MEX) Mission scheduled for December 2003 several terrestrial test flights have been carried out. Apart from a test data set of Stromboli Island, the area around the internationally renowned Alpine Instruction and Training Centre of the Rudolfshuette of the Austrian Alps has been chosen for testing (4). An area of approx. 90 km² (7.7 km W-E und 11.5 km N-S) has been covered by a high quality data take of the High Resolution Stereo Camera (HRSC) developed by the Institute of Space Sensor Technology and Planetary Exploration of the German Aerospace Center DLR. This camera is actually a one-to-one pre-runner of the actual camera which will be mounted on the Mars Space Probe.

Since this sensor is a digital three-line scanner with sensing capabilities for nadir, fore and aft looks, already three different views of the target area exist. This forms an excellent basis for the calculation of further views for the lenticular foil vision (cf. Chapter 4. Data Processing).

Since the mountains around the Alpine Centre Rudolfshuette in the Austrian Alps represent an internationally renowned skiing, hiking, rock- and ice-climbing site, the envisaged map shall and will be able to respond to an existing tourism demand. A true-colour image-line map in true 3D appears to cover the requirements best. In order to be able to view the map without viewing aids such as polarisation glasses the decision was made to generate it on the basis of lenticular lenses. These micro-lenses on a transparent plastic foil allow the map user to view the integral of two or more interlaced strips of stereo-mates through this foil with the left and right eye respectively.

The actual map area covers the major part of the so-called Granatspitz Massif in the Hohe Tauern Range, located southwest of the City of Salzburg, and just north of Austria's highest peak, Grossglockner (3794 m). The "Alpinzentrum Rudolfshuette" (2315 m) lies close to the centre of the sheet.

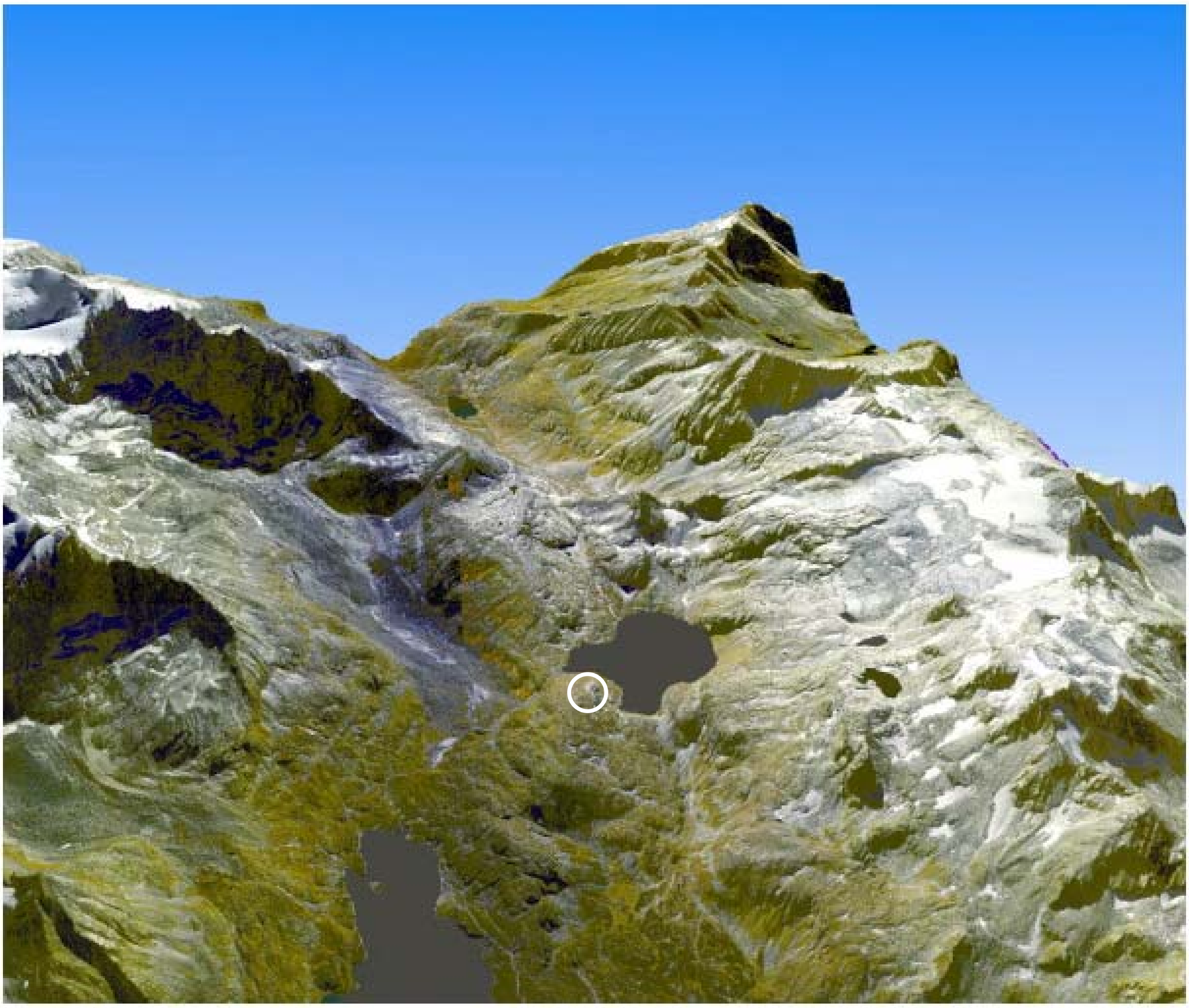

Figure 1. Area depicted by the map. Synthetic view based on DTM derived from HRSC data and draped HRSC ortho-image. Look direction SSW. Granatspitz Peak (3086 m) in the upper right corner. Circle: Alpine Center Rudolfshuette (2315 m; cf. text).

2. INPUT DATA

2.1 Topographic Base Map

The geometric base for the envisaged map area has been retrieved from an analogue copy of the so-called Alpenvereins-karte (Alpine Club Map) "Granatspitzgruppe" published by the Austrian and German Alpine Club (5). This map at an original scale of 1:25 000 has been scanned and vectorised. All the necessary relief information and lettering stems from this map. The elevation contour line plan actually stems from a plotting by the Austrian Topographic Survey. The high quality of both the official Topographic Austrian Survey Maps and the Alpenverein Maps are highly acknowledged and guarantee a sound geometric basis of the envisaged lenticular map.

2.2 Remote Sensing Imagery

The imagery has been acquired at the 14. September 1999 consisting of some 10 image strips.

The post-processing carried out at DLR Berlin-Adlershof includes in a first step the rectification of the single image strips based on DGPS and INS data. In the second step the image strips have been mosaiced to the whole image. In the case of HRSC it means, that the majority of the pixels displays synthetic radiometric values, calculated for the overlap areas of the strips which amount to nearly 50 percent across track.

Table 1. Technical data of HRSC-A, in part based on (4).

Parameter	**HRSC-A**
detector type	THX 7808B
sensor pixel size	7 µm x 7 µm
field of view per pixel (IFOV)	8.25 arcsec
active pixels per ccd line	9 sensors a 5184
radiometric resolution	8 bit
spectral filters	5 panchromatic, 4 colour
nadir, 2 stereo, 2 photometric	675±90 nm
stereo angle of stereo channel	±18.9°
stereo angle of photometric channel	±12.9°
Blue, Green, Red, Near Infrared	440±45 nm, 530±45 nm, 750±20 nm, 970±45 nm
stereo angle of Red, NIR	±15.9°
stereo angle of Blue, Green	±3.3°
maximum scan rate	450 lines/s

The original data, acquired with a ground resolution in the dm range, have been resampled to one-meter pixels. For the present test data set the NIR data are not available.

The excellent radiometric properties of the imagery proved ideal for a true-colour depiction of this high-relief terrain containing both clear water bodies and snow-covered glaciated peaks above 3000 m.

3. MAP DESIGN

In order to reach an optimum balance between the area to be covered, the geometric resolution of the remotely sensed image data, and the valuable sizes of lenticular foils, a final format of the actual map area of 51.5 cm (W-E) x 71 cm (N-S) has been chosen.

Due to the fact that an excellent image data material was at our disposal, already at an early stage the decision was made that the final product should be a so-called CIL (combined image-line) map, thus combining the advantages of a sort of photo-realistic depiction of the terrain in true-3D and the abstracted (symbolised) cartographic information (6). For further remarks on the lettering and other cartographic aspects see Chapter 5.

Based on the assessment of three tentative map layouts, a final map design with the title on the top, a centred map field, the legend and the overview map at the bottom was preferred. Some peculiarities in comparison with "normal" two-dimensional maps had to be considered. Since the lenticular foil will cover the whole map format including the margin special attention had to be paid to the legibility of all the collateral map information (imprint, legend, title, overview map). This process is determined by the initial image data resolution, the print resolution and the resolution of the human perception capability and led to a final map scale of 1:15 000. The actual layout of the map entitled (in German and English) "Granatspitzgruppe, Hohe Tauern, Österreich / Granatspitz Massif, Hohe Tauern Range, Austria" can be seen in Figure 2.

Figure 2. Layout of the combined image-line (CIL) map "Granatspitz Massif".

4. DATA PROCESSING

4.1 Geometric Modelling

Initially, some basic remarks concerning the geometry of lenticular foil true-3D maps shall be made. With reference to the renowned textbook by Okoshi1975 (7) and the paper by Buchroithner and Waelder (these proceedings; (8)), the ray geometry implied by the tunnel shape of the individual lenses can be derived from the Figures 3 and 4.

In contrast to classical parallax stereoscopy, for a high-quality true-3D representation based on lenticular technology, a number of stereomates significantly higher than two had to be calculated. In a way simulating an east-west airplane overflight a minimum of seven convergent views was generated. This is a prerequisite for a "smooth" viewing of a lenticular scene from different east-west directions. Further research in the optimisation of the lenticular techniques is planned.

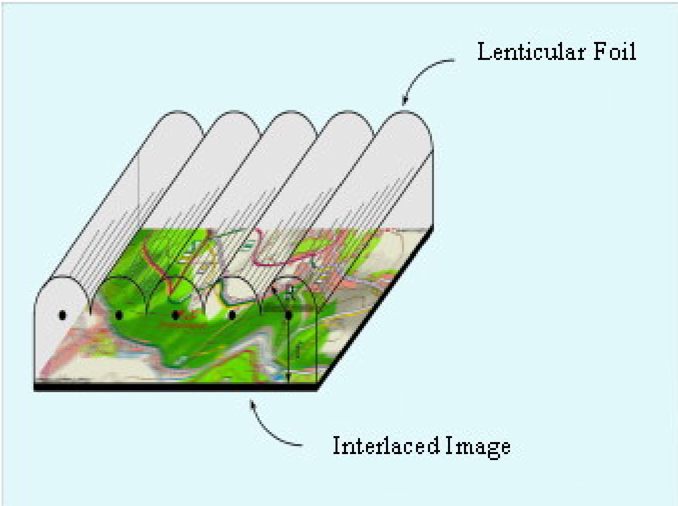

Figure 3. Scheme of lenticular foil principle.

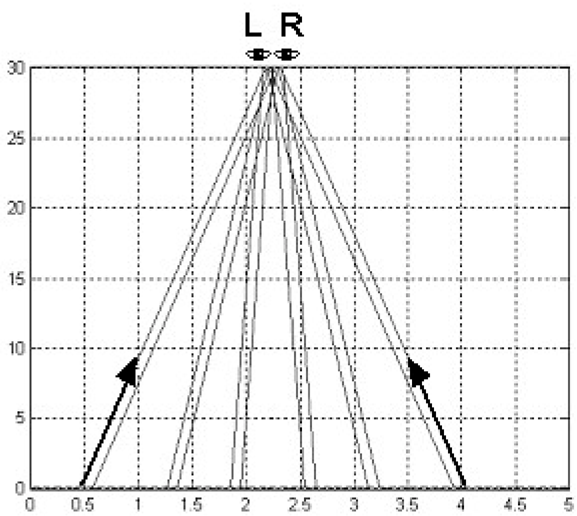

Figure 4. Direction of principal rays coming from the interlaced image
which are diffracted by the lenticular foil and then hit the human eyes (L, R).

3D outputs in digital and analogue form require an interface to existing modelling and output systems. The problem of the optimal matching the cartographic information with relief surface is discussed presently in MEX-Group. As far as these aspects are concerned, initial experiences with AutoCAD and 3D-StudioMAX have been gained. For high-quality hardcopies algorithms and methods have to be developed and tested which aim at the operational production of high-resolution 3D visualisations based on lenticular sheets.

The calculation of the single 3D-views was carried out by means of the software packages SCOP++ and SCOP classic (TU Vienna) for the image data and 3D Studio MAX for the vector data and cartographic names. The computation of both the strip width and the interlacing was accomplished using the commercially available software MAGIC INTERLACER Pro 100, a plug-in for Adobe Photoshop.

4.2 Graphic Modelling

An indispensable requirement for the generation of a homogeneous image map is the brightening of the shadows and cast shadows (cf. Figure 1). Due to the fact that most of the shadow areas are represented by synthetically calculated pixels of the merged individual image strips, the generation of a shadow mask was not possible based on a rigid geometric calculation but had to be materialised by shadow classification. Subsequently, correlation parameters derived for certain reference areas were used to compute the “de-shaded” image portions in a way that still the slightly darkened radiometric features of the respective areas can be easily observed. Moreover, this enhances the relief perception, since this “synthetic shadow” serves as a sort of analytical hill-shading.

5. CARTOGRAPHIC WORK

One big advantage of a true 3D map based on the lenticular foil technology is, that the whole vector information, i.e. the map symbols and the lettering, in particular the geographic names, can be modelled in a way that they are not hiding the actual surface- (image texture) or relief information (elevation contours, spot heights) and seem to hover over the terrain, cf. (2, 3). The same applies to the cables of the cable cars.

Several cartographic elements, however, had to be kept “on the ground” in a conventional way: marked trails, sign post, summit crosses, foot bridges, etc.

The software used for cartographic work is MACROMEDIA Freehand and 3D-StudioMAX.

6. CONCLUSIONS

The generated represents the first high-mountain map ever which can be viewed in true-3D with unaided eyes. Apart from frequently applied true-3D visualisations on digital displays, this hardcopy map has the big advantage that it can be easily moved and viewed by various persons simultaneously. This implies that it can also be moved into the field, either as a whole or cut into partitions which are cloth-bound. The biggest advantage, however, is that this type of map needs neither a particular illumination like a hologram nor particular viewing means like anaglyph (red/green) glasses or similar. The combination of image data (artificial or natural) shading and - partly hovering - topographic line information yields an optimum for the map user. To this end, by combining all the above mentioned assets the described map represents a novelty in the cartographic visualisation of the third dimension which yields tremendous benefits for all those who until now had serious troubles in deriving relief information. In this sense, it has an enormous potential for future applications both in topographic and thematic cartography.

Today, photogrammetric processing and cartographic work are supposed to be made completely digitally. As far as the production of lenticular foil maps is concerned, this is, however, a rather optimistic point of view. Still, for the generation of a high-quality graphic output of high-resolution 3D hardcopies interim steps of visual human quality control have to be foreseen. However, the transformation of digital 3D models into appropriate true-3D maps shall be automated as far as possible.

7. ACKNOWLEDGEMENTS

Most of the work described in this paper has been carried out within the contributions of the Dresden University of Technology to the scientific programme of the so-called Marx Express Mission (MEX). They actually focus on the development and application of methods for the generation of true-3D visualisations based on imagery acquired by the DLR high resolution stereo Mars camera. Financial support by the German Aerospace Center (DLR) and the Federal Ministry of Education and Research (BMBF) as well as test data supply and other assistance by the staff of the DLR Institute of Space Sensor Technology and Planetary Exploration is highly acknowledged.

8. REFERENCES

[1] M.F. Buchroithner, R. Schenkel, 3D Mapping with Holography. In: GIM International, 13 /8, p. 32-35 (1999).

[2] M.F. Buchroithner, Erste Holographische Hochgebirgskarte. Salzburger Geograph. Arbeiten, Vol. 36, p. 39–47 (2000).

[3] S. Kirschenbauer, M. F. Buchroithner, "Real" 3D Technologies for Relief Depiction. In: Proc.19th ICA Intern. Cartogr. Congress, Ottawa/Canada, August 14-21, 1999, p. 1-7.

[4] E. Hauber, R. Jaumann, F. Wewel, K. Gwinner, G. Neukum, H. Slupetzky, The Airborne High Resolution Stereo Camera (HRSC-A) as a Tool for High Mountain Cartography, Kartographische Bausteine, Vol. 18, TU Dresden, p. 29-38 (2000).
[5] Österreichischer Alpenverein (Austrian Alpine Club; Ed.), Alpenvereinskarte Granatspitzgruppe 1:25 000, Innsbruck (2002).
[6] M.F. Buchroithner, R. Kostka, Conceptual Consideration on High-Mountain Cartography and Spaceborne Remote Sensing. In: Proc. 18th ICA/ACI International Cartographic Conference, Stockholm 1997, Vol. 4, p. 2056-2059 (1997).
[7] T. Okoshi, Three-Dimensional Imagery Techniques, New York Academic Press, 403 p. (1976).
[8] O. Waelder, M.F. Buchroithner, True-3D Presentations of the Mars Surface, Proc. 21st Internat. Cartographic Conf., Durban, 2003 (in Print).