# PC-BASED DIGITAL PHOTOGRAMMETRY

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## SUMMARY

The introduction of digital photogrammetry has changed the world of photogrammetry completely. Today it is not anymore necessary to use the former required expensive hardware components, if digital images are available. So only a qualified scanner is requested if the traditional aerial photos shall be used. The University of Hannover in cooperation with the University of Düsseldorf, both located in Germany, has developed a software system which includes the measurements of image coordinates as input for block adjustment, the bundle block adjustment, measurement of a digital stereo pair, DEM-generation by automatic image matching, the filtering of elements not belonging to a DEM, orthophoto generation, mosaics of orthophotos and the processing of DEM. The processing of the Digital Elevation Model includes the computation of contour lines, 3-dimensional representation and more. The whole program system is PC-based and simple to be handled. So today with very little effort, the whole world of photogrammetry is available on standard PC's.

## 1. INTRODUCTION

Photos are information about the imaged objects, but information without geometric reference is useless. The photogrammetry is giving us the 3-dimensional reference for our semantic information. Over long time analog and analytical photogrammetry has dominated, both are proven techniques, but they require expensive instruments. Today even standard PC's are powerful enough to handle aerial or space images with the full resolution, so the digital photogrammetric applications can be handled on simple PC's. The only necessary hardware component beside the computer for digital photogrammetry is the image scanner if analog images have to be used. If the full accuracy range of the photogrammetry shall be used, special photogrammetric scanners are required because the desk top publishing scanners are limited to an accuracy of approximately +/-50µm, even if the resolution may be sufficient.
The important advantage of the digital photogrammetry is the possibility of automation. Automatic image matching is today not too time consuming, it is much faster than the manual measurement of a Digital Elevation Model (DEM).

All the required steps from the digital image to the final result are available in the program system SIDIP, developed by the University of Hannover in cooperation with the University of Düsseldorf.

## 2. IMAGE RESOLUTION

Standard aerial images do have a resolution of approximately 40 lp/mm, corresponding to approximately 80 pixel/mm or a pixel size of 12µm. Scanning with a smaller pixel size does not give more information about the image, it only will show the grain.
With analytical plotters an image accuracy of 5µm can be reached. The digital photogrammetry should be able to do the same. The measurement in digital images can be based on the full pixel addresses or in the case of zoomed images also with sub-pixel accuracy. By theory in the case of the measurement just based on pixel addresses, an accuracy of 1/3 of a pixel can be reached, because the largest error of the registration can be just 0.5 pixel and by the integration over several measurements, this corresponds to +/-0.3 pixel. But in the photogrammetry no points in the mathematical definition – without dimension -are used, we are handling the centers of small areas. Based on this even a higher accuracy is possible by calculation or by measurement in a zoom-window. That means there is no reason for a smaller pixel size than 12µm.
An aerial photo with a size of 230mm x 230mm corresponds to a file size of 340Mb for black and white images, scanned with 12µm pixel size and 256 gray values. For larger blocks, a high amount of data will be created. By this reason, under operational conditions, usually only a pixel size of approximately 24µm is used, corresponding to 85Mb per image. With this pixel size, no important loss of accuracy against analytical photogrammetry will happen.

## 3. PROGRAM SYSTEM SIDIP

The program system SIDIP (Simple Digital Photogrammetry – simple to be used, but highly qualified solution) includes four mayor components:

DPLX for the measurement of digital images; integrated is also the image matching in the image space by least squares solution with DPCOR

BLUH, the bundle block adjustment program system including a photogrammetric toolbox

LISA-FOTO for the photogrammetric solution

LISA-BASIC for the handling of DEM, including also simple image procession

The standard handling will be the determination of the image coordinates of control and tie points by manual measurement, which may be supported also by precise pointing by means of an ellipse operator with DPLX. This will be followed by the bundle block adjustment with BLUH, creating the required orientation parameters for LISA-FOTO, so directly after the bundle block adjustment, without additional measurements, the stereo handling can follow. A standard solution will

be the determination of the DEM by image correlation in LISA-FOTO, followed by a filtering of the data from the visible surface to the ground by program RASCOR. Based on this, orthophotos and mosaics can be generated. With LISA-BASIC contour lines can be computed and overlayed to the orthophotos. Different products like 3-dimensional views can be generated.

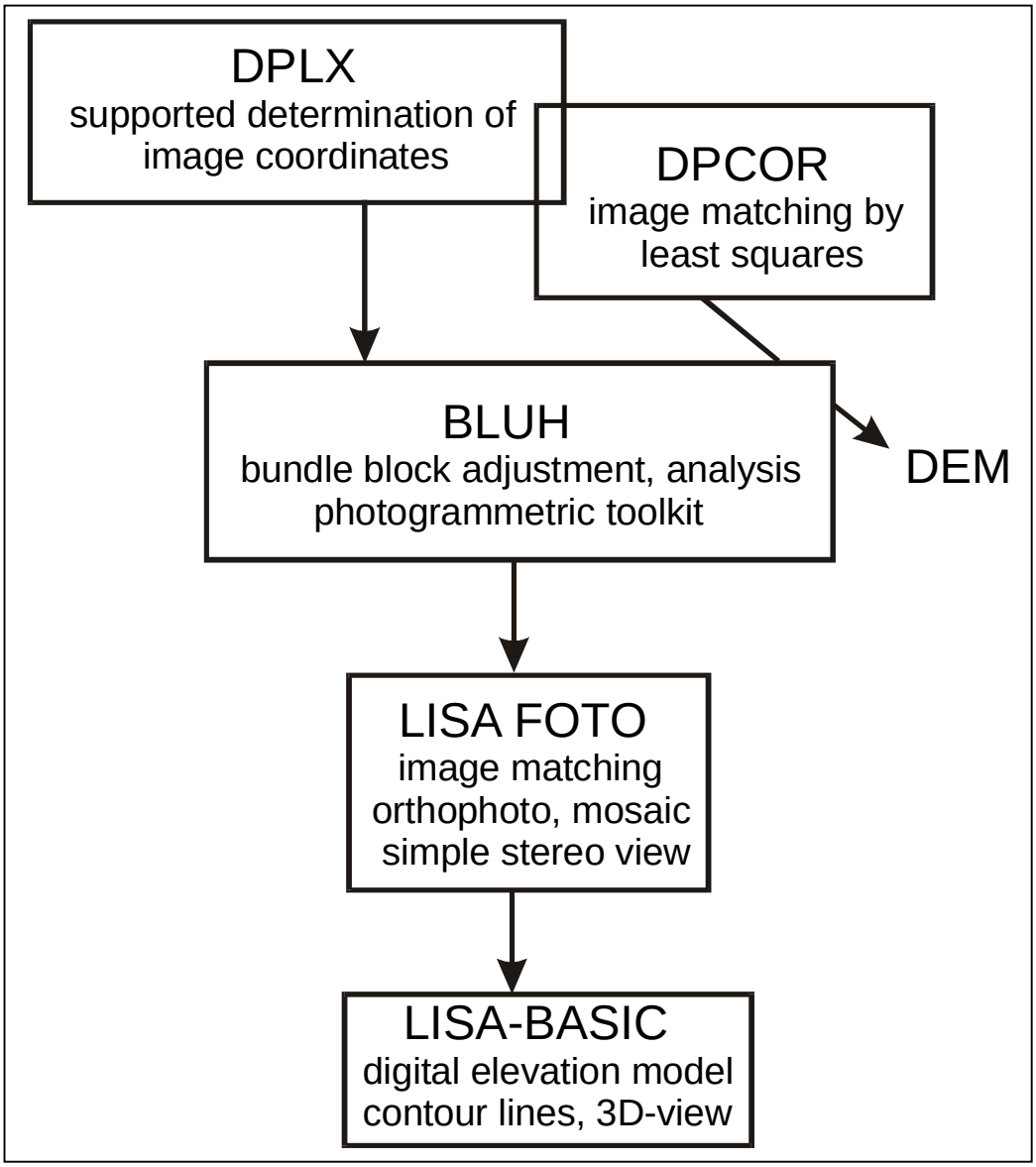


Figure 1: overview of program system SIDIP

**3.1 DPLX**

DPLX has been developed for the precise determination of image coordinates in digital images as input values for a bundle block adjustment. The center of symmetric targets can be identified automatically. The image matching program

DPCOR for the determination of the visible surface by means of the least squares method is integrated.
Also large images can be handled without problems on usual PC's, based on a segmentation of the original images. Overview images will support the point handling in the actual image windows and the optional zoom-windows.

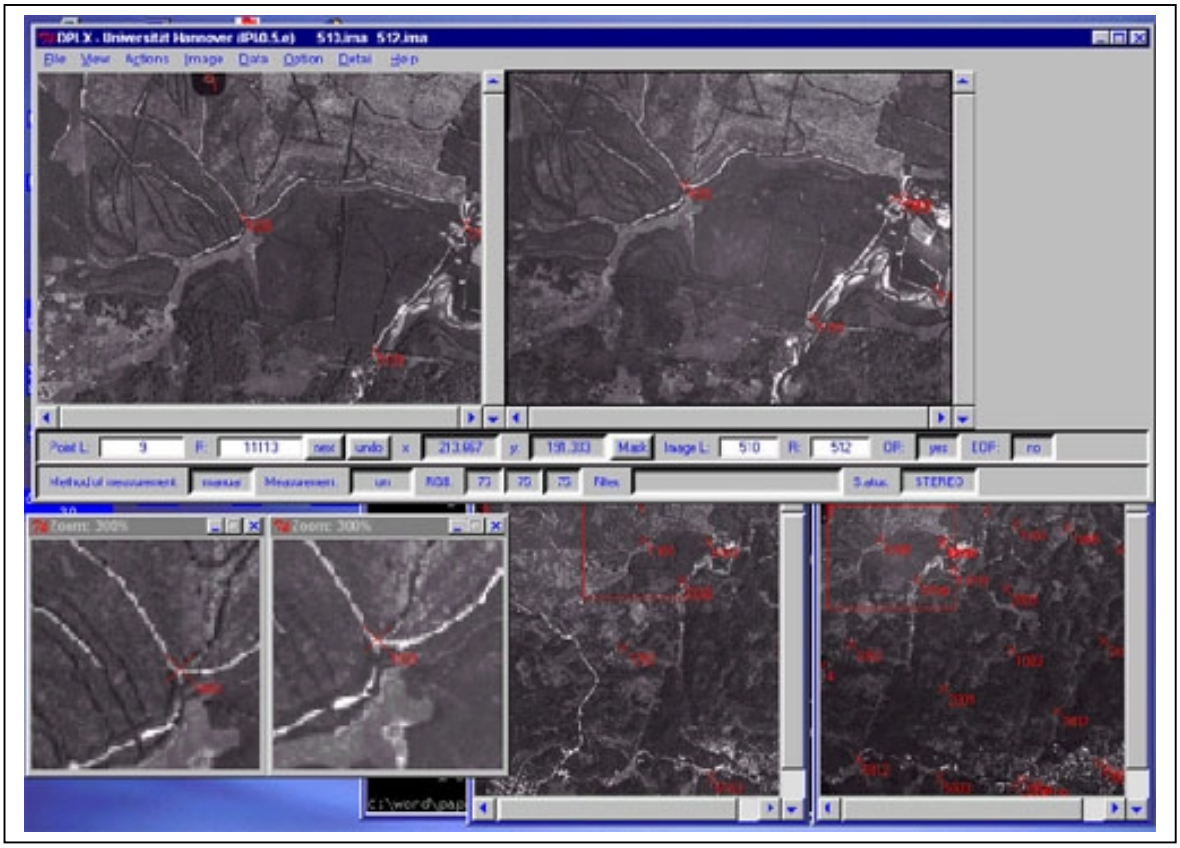

Figure 2: representation of DPLX on the screen

The size of the individual windows is optional. The measurements can be made in the active windows (1 pixel on the screen = 1 pixel in the digital image) or the zoom window. The measured points can be marked like shown above. Points can be renamed or deleted. The standard image processing tools like change of brightness or filtering are included.
In the shell of DPLX, the program DPCOR for matching the 2 images of a model is integrated. The exterior orientation is not required for this. The start values for the matching are determined by a region growing method. Based on corresponding points in both images, which can be measured in DPLX, the matching of neighbored points is growing over the images. By this method no image pyramids have to be computed and the solution is very robust. After a first matching by correlation, the exact values are computed by least squares, the most accurate method of image matching.
The automatic image matching in the image space includes the advantage to be independent upon the image geometry. So any geometric situation of space images can be handled without change of the software.

## 3.2 BUNDLE BLOCK ADJUSTMENT WITH BLUH

Bundle block adjustment is the most rigorous and flexible method of block adjustment. The computation with self calibration by additional parameters leads to the most accurate results of any type of block adjustment. Even based on the same photo coordinates an independent model block adjustment cannot reach the same quality; this is due to the data reduction by relative orientation, the comparatively inexact handling of systematic image errors and the usual separate computation of the horizontal and the vertical unknowns by independent model solutions. The program system BLUH is optimized for aerial triangulation but not limited to this. Even close range photos taken from all directions (with exception of omega = 80 - 120 grads) can be handled. A camera calibration for close range applications, also for special optics like fisheye, is possible.
The program system BLUH is very flexible. There are no restrictions to fixed formats of the input data and several different data structures of photo coordinates and control points are accepted. In addition the high number of service programs are offering several possibilities of the handling of special or defected data sets. Intensive possibilities of data analysis and graphical representations are included.
The program system BLUH is an extensive system of programs well grounded on statistics with a high degree of automation. No estimates of the unknowns are required. Blunders are identified by the method of data snooping and robust estimators. Extensive pre- and post processing do enable the handling also of special data sets with not perspective geometry. Graphic representations are simplifying the data analysis and do give an overview over geometric weak parts of the block.
Because of the rigorous mathematical model and the self calibration only few control points are required. In the center of the block horizontal control points are not required and with crossing flight strips the number of vertical control points can be minimized.
Functions:

- self calibration by additional parameters
- individual weights for control points, different weights for groups of photo coordinates
- error analysis by robust estimators and data snooping
- high number of plausibility checks
- automatic computation of estimates of all unknowns
- handling of very large blocks also with not regular photo distribution
- based on combined adjustment with projection center coordinates determined by kinematic GPS-positioning and/or IMU-data by theory block adjustment without control points, in practice handling of the block adjustment with a minimal number of control points - e.g. 4 control points also for large blocks, or even without control points
- extensive statistical analysis of the results

- functions for the support of data sets based on the data acquisition by automatic aerial triangulation, like handling of high amount of points and supported blunder elimination
- graphical representation of the results
- covariance analysis
- analysis of the results by comparison with another data set
- post processing by least squares interpolation
- a posteriori improvement based on distances between points
- handling of space images and panoramic photos
- transfer of the orientations to analytical and digital plotters
- camera calibration
-determination of IMU misalignment, transformation IMU-data to photogrammetric image orientation, combined intersection based on IMU + image coordinates

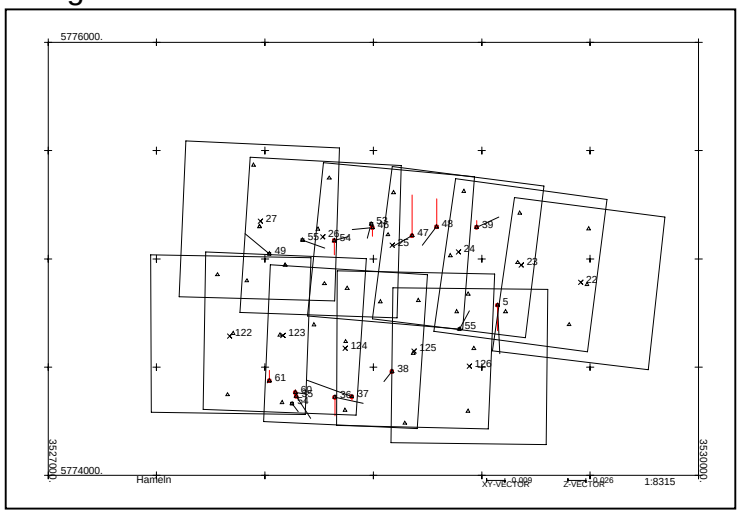


Figure 3: graphical representation of the results of the bundle block adjustment

The program capacity is with 6000 photos and 200 000 ground points sufficient for any type of blocks.
By bundle block adjustment the photo orientations, which are required for the model handling and the creation of orthophotos are computed and transferred to LISA. The inner orientation parameters, determined by DPLX are also transferred, so LISA-FOTO can start directly with the stereo model handling.

### 3.3 LISA-FOTO

LISA-FOTO combines the function of a simple photogrammetric workstation with the automatic generation of a digital elevation model by image correlation, the generation of orthophotos and mosaiking. The results from LISA-FOTO can be transferred to LISA-BASIC for the generation of contour lines or other DEM-results.

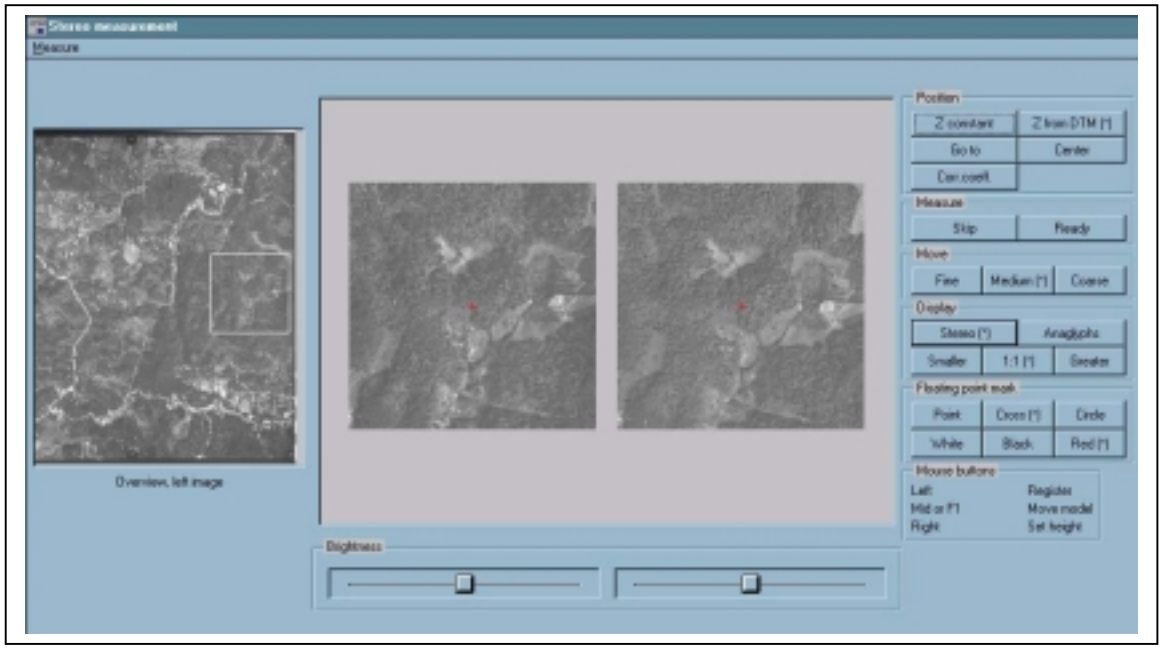


Figure 4: model handling with LISA-FOTO

By default, the floating mark will be kept on the surface based on an on-line-correlation which may be supported by a DEM. The stereo view can be achieved with a simple stereoscope or by anaglyphic display. The ground coordinates are displayed.
Based on existing inner and exterior orientation together with the determined DEM, orthophotos can be generated. Orthophotos can be mosaiced – it is possible to generate a cut line of the individual orthophotos. In the overlapping part of the neighbored orthophotos the mean of the gray values or the gray values of a defined image can be used.

### 3.4 FILTERING DSM TO DEM WITH RASCOR

By automatic image matching, the height of the visible surface (Digital Surface Model = DSM) will be determined. For cartographic applications, not he DSM, but the height of the solid ground is requested. By a simple filtering this cannot be computed based on a DSM because a simple filter will go to the mean height between the vegetation, buildings and the ground, that means other techniques are required.
Program RASCOR can analyze, improve, smooth and interpolate a digital elevation model (DEM) which may be created by automatic image matching or laser scanning (LIDAR) in an equal spacing arrangement. Blunders can be eliminated and a graphical representation as isometric plot by means of HP/GL-files is possible. For not equal distributed points, program DTMCOR should be used.
The identification of points not located on the solid ground but on topographic features like vegetation and buildings is possible by a minimal and maximal

height in the area, by maximal height differences between neighbored points, by a sudden change of the height level, by a linear or polynomial interpolation in X- and Y-direction, by a minimal and maximal height difference against a local tilted plane or polynomial surface and a local prediction (least squares interpolation) based on the tilted plane or polynomial surface. The final results can be filtered (smoothened) in relation to a rotated plane or polynomial surface fitted to the neighbored points.

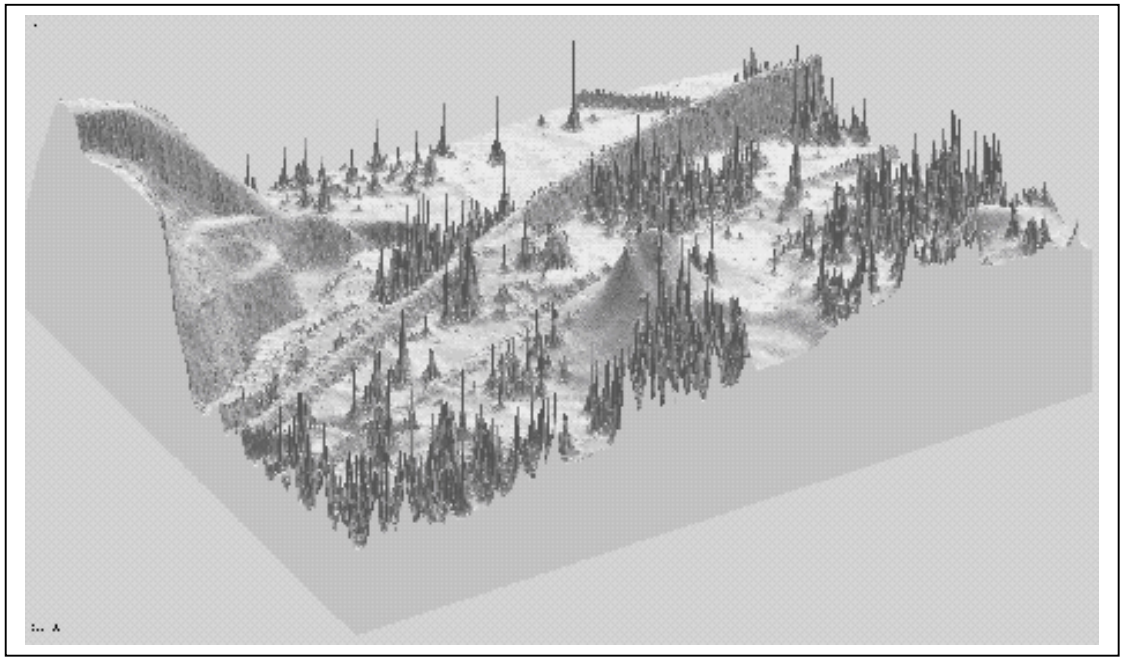

Figure 5: original DSM

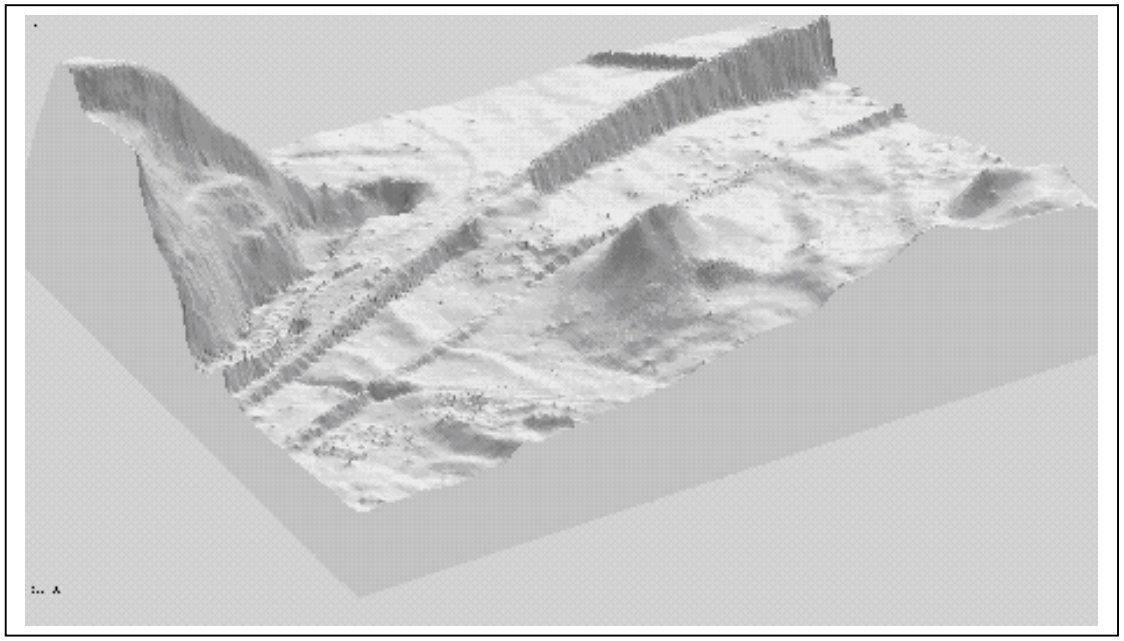

Figure 6: DEM filtered by RASCOR without manual interaction

The required parameters can be automatically determined by an analysis of the DEM based on a simple characterization of the area as homogenous or not and smooth or undulated or very undulated.
The simple, automatic handling of RASCOR has reduced the manual editing of qualified elevation models to a minimum.

### 3.5 LISA-BASIC

LISA-BASIC is a general DEM-program. Based on random or equal distributed height points, optionally supported by break and form lines an equal distributed DEM can be created. Internally the DEM is handled as an image with gray- instead of Z-values. This has the advantage of a very fast computation of all derived products like contour lines, wire frame models or 3-D-views.
The program is not limited to a simple generation of a digital height model, beside numerical results like volumes or volume differences also the basic tools for image processing are included.
In general, the graphical results can be created as image file or as plotter file. In the display mode an on-line digitizing is possible. That means, also a simple mapping based on orthophotos is possible. The result can be exported as BMP-, PCX or DXF-file.
An orthophoto can be draped over a 3-D-view from a chosen direction and inclination of the DEM to create an inclined perspective view based on aerial images.

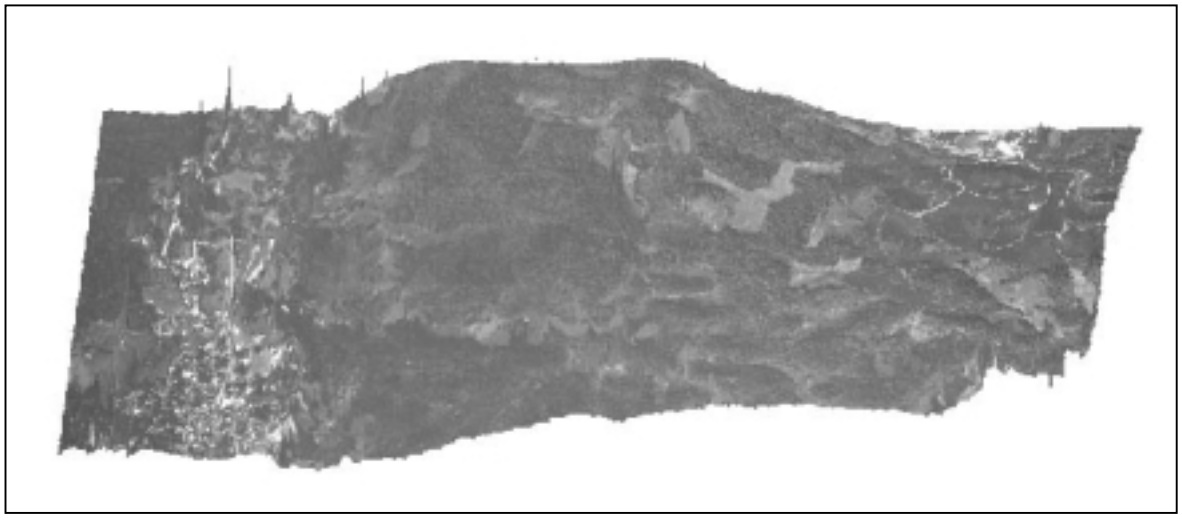

Figure 7: orthophoto draped over 3D-view of DEM

Figure 8: orthophoto with overlay of automatic generated contour lines

### 3.6 HANDLING OF SPACE IMAGES

Satellite line scanner images, panoramic or perspective images can be handled in the program system. Satellite line scanner images have to be handled with the special program BLASPO, which just requires the view direction for the solution. For space images the automatic image matching should be made with the module DPCOR, which is independent upon the image geometry. The ground coordinates can be computed by mans of program COMSPO, using the orientation determined by BLASPO.

## CONCLUSION

Today the handling and use of digital images on standard PC's is possible up to the final production of orthophoto mosaics and contour lines without problems. The hardware of analog and analytical plotters can be replaced by qualified software, which can be handled without very intensive training - it is "only" a question of software (50 man years).