LISA®

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LISA Geo-Software GmbH
Ludwig-Erhard-Ring 30
D 54296 Trier
http://www.lisa-geosoftware.de

Amtsgericht Wittlich, HRB 40926
Geschäftsführerin Elke Giese-Linder

Survey

Please read before starting the programme

This programme was carefully developed and intensively tested. Nevertheless, due to the complexity of such software it cannot be excluded that errors were not detected during the programming and testing. Such errors may occur for instance when seldom sequences or combinations of commands are carried out, or if the input data have unusual formats or an extraordinary size.

To prevent you as the user from following damages, we strongly advise you to check the plausibility of all results given by this programme before any further use of the data.

If errors occur, we kindly ask you to inform us about them, if possible together with the corresponding data set. We will do our best to correct the programme as soon as possible, and we will wend you the actualised version free of charge.

Representation in this programme description

For a better readability some contents are printed different from the normal text:

Options and menu paths as small caps, e.g. INPUT FILE, FILE > SAVE AS
Directories and file names in the typeface Courier, e.g. …\LISA\TEST, SIGNATUR.DAT
File examples are printed with grey background.
Move to cross references with a click at e.g. Installation.

Requirements

Hardware: Graphics resolution minimum 1024 x 768 pixels, mouse with 3 buttons or central wheel.
Operating system: MS Windows 7 or higher.

Installation

Please start the computer with full rights (as administrator); otherwise the installation will not work properly. Then start the programme SETUP.

PROGRAM DIRECTORY: Usually LISA should be installed within the Windows programme directory (e.g. C:\PROGRAM FILES (X86)\LISA). SETUP will create there the directory LISA as well as some sub directories and copy several files to them. No changes are made in the Windows registry database.

CREATE START MENU ENTRIES: Create the respective entries if activated.

CREATE SHORTCUTS: You can select whether the programme icons should be created directly on the main screen (DESKTOP ICONS) or within a separate directory (DESKTOP FOLDER). If you don't want programme icons, select NONE.

ACTION: Select INSTALL.

De-Installation

The SETUP programme can also be used for a complete de-installation of LISA software. Select the respective programme directory and as ACTION the option UNINSTALL.

Attention: All data in the programme directory and in all subdirectories will be deleted!

Directory structure

During the installation the following directories and files are created on your computer:

`C:\PROGRAM FILES (X86)\LISA`	programme files (extension .exe) font files (extension .fnt) runtime libraries (extension .dll)
`C:\PROGRAM FILES (X86)\LISA\TEXT`	this programme description
`C:\USERS\PUBLIC\LISA\PAL`	directory for palettes
`C:\USERS\PUBLIC\LISA\SIG`	directory for area symbols
`C:\USERS\PUBLIC\LISA\FLT`	directory for filters
`C:\USERS\PUBLIC\LISA\CAM`	directory for camera data

General remarks, conventions

LISA is project oriented. A project consists of a working directory, co-ordinate range, pixel size and an optional image data base (see option FILE > PROJECT DEFINITION). With the exception of palettes, area symbols, filters and camera data, all created files are stored herein and all input files will be searched here.

File names including the path may consist of up to 120 characters. Details about the LISA-specific data formats are given in the Appendix. The button ... opens a file selection window.

Directions are reckoned clockwise from North = 0°, therefore East = 90°, South = 180° etc.

Numerical values require a decimal point, not a comma (for instance 3.14 instead of 3,14).

Instead of the button OK offered in each input window the Enter key may be used. Instead of the CANCEL or BACK button it is possible to use the ESC key. In addition, the often used options to display data can be called directly with the buttons right in the main window or using a pop-up menu: click anywhere in the main window using the right mouse button and a menu will be displayed providing the options to start the display of a raster image, a vector graphics, text or attributes.

Error messages

"Error reading input file": The file is incomplete or destroyed or the format is not correct.

"Error writing output file": Usually there is not enough storage capacity, or the storage media is write-protected (for instance, a CD-ROM).

"Files do not fit together": This message may refer to one or more of the following parameters: No. of image rows and columns, depth of image [bit], co-ordinates of the lower left or the upper right corner, pixel size, height range (for DTMs).

Help function

For this option, a programme to display PDF files must be installed. With a click onto the button HELP or using the F1 key, this programme will be started and the LISA programme description (= this file) loaded. In case of problems please check first if the respective file exists in the subdirectory `TEXT`.

Explanations of often used keywords

Binary image: Contains only two colour values, i.e. 0 (black) and 255 (white). Is also called black-and-white image or mask and stored in LISA as 8-bit image.

Colour value: Each pixel of an 8-bit image is represented by a number from the interval 0 ... 255. The corresponding colour is given in the palette. 24-bit images have 3 colour values per pixel (for red, green and blue) but no palette.

Geo-coded: In LISA the term is used for raster images which are north-oriented in relation to a terrain co-ordinate system, so that the corner co-ordinates and the pixel size (geometric resolution) are known. Synonym: rectified.

Grey value: Each pixel from a 16-bit DTM is represented by a number from the interval 0 ... 32767. This value corresponds to the terrain height.

Oriented: In LISA the term is used for raster images which are connected to a terrain co-ordinate system by the parameters of an equation system, but are not geo-coded. Synonym: geo-referenced.

Raster image: An image made up of individual points. The smallest unit is the image point (pixel). The size of the image is determined by the number of points in row and column direction. In a digital raster image every pixel is represented by an entry which specifies its colour. All pixels follow one another sequentially in rows (“byte map”).

Resolution: You can distinguish between geometric and radiometric resolution. The geometric R. can for instance in case of an aerial or satellite image give the edge length of a pixel in the terrain (ground resolution). The number of different grey- or colour values of an image is a measure for the radiometric R.

Programme versions

LISA is offered in different versions. The included programmes, the available functions and the maximal number of images which can be processed in BLUH simultaneously as block vary depending on the version:

Version	No. of images	Programmes	max. image size
Test	≤ 30	BASIC, FOTO, BLUH_30	20 MB
Unlimited	---	BASIC, FOTO (without ATM)	500 MB
... or	≤ 200	BASIC, FOTO, BLUH_200	500 MB
... or	≤ 500	BASIC, FOTO, BLUH_500	500 MB

LISA BASIC

File

Starting LISA, a project has to be declared. With this, a working directory, an optional image archive, a co-ordinate frame (minimum and maximum for x, y and z) and a pixel size will be defined. In the working directory all input files are searched for and all output files are stored.

The project definition files have the extension PRJ and are located in the programme directory.

File > Select project

Corresponds to a new start of the programme. Alternatively, the last used project can be taken, one of the existing projects can be chosen or a new project can be defined:

File > Project definition

The following parameters have to be defined:

- Name of the project. From this, the definition file (extension PRJ) will be generated.
- Working directory (folder).
- Image data base (optional, see programme part Database).
- Co-ordinate range in x, y and z. The button RESET puts the co-ordinate range to the maximum possible one, it is then without meaning. A unique value range for z is very important for the generation and matching of DTMs!
- Pixel size (geometric resolution in the object space).
- Length unit (µm, mm, m or km).

> The pixel size and the range of the z-values are valid for all data of a project! Therefore these values should definitely be chosen carefully!

The co-ordinate limits can be overtaken from an already existing project, a geo-coded raster image or a vector file (buttons TAKE OVER, REFERENCE RASTER or REFERENCE VECTOR).

Example for a project definition file:

`C:\STEREO\CAICE\`	working directory
`1135300.0000    1141800.0000`	co-ordinate range in x
`968200.0000     974300.0000`	... in y
`5.0000`	geometric resolution (pixel size)
	optional image database
`1000.0000       1700.0000`	co-ordinate range in z
`3`	length unit

File > Edit project

The parameters of the actual project with exception of the project name and the working directory can be modified here.

File > Import

Input formats, vector: AutoCad DXF, ASCII files with any sequence (e.g. CSV), dBase DBF, ArcInfo E00, MapInfo MIF/MID.

Input formats, raster: Arc/Info ASCII, GTOPO30, SRTM (each 16 bits).

AUTOCAD DXF: All lines up to the entry ENTITIES are skipped. Co-ordinates which follow the entries LINE or POLYLINE (and then VERTEX for several times, until SEQEND) are rated as points on one line. Co-ordinates after VERTEX without previous POLYLINE or after POINT are rated as single points. All other entries will be ignored.

ASCII ANY SEQUENCE: Universal import filter for files containing the required entries x, y, z as well as optional the number for each reference point within one line, but in an unusual order or sprinkled in among other pieces of information. Example: In each line the entries

point No. code_1   z   code_2   x   y   operator

are stored in. For the processing in LISA, however, the data must look like this:

point No.   x   y   z

Accordingly, the position of the number has to been set to 1, of the x-value to 5, of the y-value to 6 and the one of the z-value to 3. For instance, CSV files can be processed here. For a maximum of 15 numerical entries within one line and a maximum line length of 200 characters.

DBASE DBF: The input file must contain each a field for the x and the y co-ordinates. From the remaining fields, a numerical one must be chosen from which the z-values are taken. Values for x, y and/or z which cannot be read are set to -999999.

ARCINFO E00: Entries of lines (part ARC) as well as points (parts CNT or LAB) will be adopted. Lines will be given a code according to the so-called coverage-ID (if lower than 5001, increased by 5000). Individual points are given the code 1 and the so-called centroid number from the input file.

MAPINFO MIF/MID: Adopted are entries of the types POINT, LINE, PLINE, PLINE MULTIPLE and REGION. A numerical field of the MID file can be used to give the z values, otherwise the z values will be set to -999999.

GTOPO30: Beside of the image file (extension DEM) a file of the same name but with the extension HDR (additional information) must exist. Optional, the part of the DTM situated within the project area can be transformed to one of the projections Gauss-Krueger or UTM.

SRTM: Optional, the part of the DTM situated within the project area can be transformed to one of the projections Gauss-Krueger or UTM.

File > Export

Output formats, vector: AutoCad DXF, CSV, dBase DBF, ArcInfo E00 (only lines), MapInfo MIF/MID, HP-GL 1.

Output formats, raster: Arc/Info ASCII 16 bits, DAT / vector.

Note: In the vector data display, vector data can also be converted into the raster image formats BMP or JPG or transferred into other programmes using the clipboard (ADDITIONALS > COPY).

CSV: The contents of the input file will be exported without point numbers and codes and with commata as separators.

DBASE DBF: A DBF-file with three numerical fields (x-value, y-value and z-value) is generated, each of which having 12 digits with 3 decimals; the name of the third field may be altered. This file can be used to generate an attribute file, for instance by replacing the z-value field by another and/or adding further fields (option DISPLAY ATTRIBUTES, then EDIT).

HP-GL: For output on a plotter. The file can be viewed in the graphics display of BLUH.

DAT / VECTOR: The input image must be geo-coded. Output is a vector file with the z-values derived from the input image.

- Single point or profile data: The x/y-values are taken from an input vector file. For profiles, the interval (= distances between points) must be defined.
- Grid data: Defined by the grid width. As an option, for each pixel of the input image a point may be issued (ALL POINTS).

Points within the raster image for which no information is available (colour value = 0) will not be transformed.

Vector data

Vector data > Control points

For creating or editing a control points file. The number of control points needed depends on the transformation method; a maximum of 900 points can be processed there. The co-ordinates have to be given in a Cartesian system (e.g. Gauss-Krueger or UTM) and should be well distributed within the area. If the map gives only geographic co-ordinates (longitude, latitude) these values must first be transformed to Gauss-Krueger or UTM (see VECTOR DATA > PROJECTIONS).

Vector data > Define symbols

Single points of the codes 3501 ... 3600 can be connected with vector symbols. There are 10 standard symbols (circle, cross etc.) which can be modified in size. A file named `VEC_SYMB.DAT` will be created in the actual working directory.

Vector data > Projections

This option is for the transformation of vector data between several co-ordinate systems. For example, non-cartesian geographic co-ordinates (longitude, latitude) can be transformed to Cartesian (metric) systems like Gauss-Krueger or UTM. Projections:

- Geographic → Gauss-Krueger
- Gauss-Krueger → Geographic
- Geographic → UTM
- UTM → Geographic

Geographical co-ordinates have to be entered in the order x = longitude, y = latitude and in the unit decimal degree or degree/minute/second as one number (example: 7 degrees 12 minutes 24 seconds is entered as 71224). Further: Eastern longitude → positive values, western longitude → negative values. Northern hemisphere → positive latitudes, southern hemisphere → negative latitudes or option SOUTHERN HEMISPHERE activated. For the entering of the zone: This may be given explicitly in case for example co-ordinates of another than the actual zone in question shall be calculated. Otherwise the zone is calculated automatically from the longitude value.

Gauss-Krueger and UTM data have to be entered in the order x = Easting, y = Northing resp. x = East, y = North and in the unit meter. For UTM → Geographic the zone must be defined. The Northing values of UTM co-ordinates of the southern hemisphere are according to definition to be entered with an addition value of 10000 km and option SOUTHERN HEMISPHERE activated or as negative numbers. If an area is located both north and south of the equator, either all north values should be increased by 10000 km and the option SOUTHERN HEMISPHERE activated or values south of the equator must be negative (example: Ecuador).

For special applications, the position of the co-ordinate centre in degrees as well as the corresponding co-ordinates in metres can be defined explicitly.

Vector data > Vector → Raster

SITUATION OVERVIEW: Points can be entered with their numbers or height values.

AREA FILLING: Precondition besides a vector file containing the geometry in the shape of one or more polygons (closed polylines) is an attribute file (DBF) with anchor points (one point per polygon). Choose a numerical field out of these attribute files. The value range can be joined to classes (intervals) using one of the following methods:

- Equal distances with given number of classes
- Equal distances with given width of classes
- Equally distributed, number of classes pre-defined
- According to natural breaks. The size of the interval which shall be interpreted as a break can be defined using the parameter class width.
- User defined by a limit values file, containing in each row the data "from", "to" and colour value.

Example for a file with limit values:

```
12.8   20.7   6
20.7   28.4   7
```

The values between 12.8 and 20.7 will be given the value 6, those between 20.7 and 28.4 the value 7. The parameter "to" is inclusive, so in the example above a value of 20.7 would belong to the first class (6). Then the programme fills the polygons with the colour value defined by the class number.

In the special case that all z values are integers in the range between 0 and 255, instead of a classification the option CLASS = Z VALUE can be used).

Note: It is important that the single areas are bordered by closed polylines. Especially these have not only to be closed optically but mathematically as well (the co-ordinates from the first and the last point are identical)! In order to meet this precondition, for example you can use the option DISPLAY VECTOR GRAPHICS and then EDIT > MOVE, or when digitising, the button CLOSE. For the area filling, colour values between 2 and 254 are used.

FREE CUT AREAS: If the input file consists of one or more closed polygons (code 9008) and of one or more starting points for deletion (code 4007), only the marked areas for not free cutting of the input image will be taken over into the output image (masking function).

Note: The option DISPLAY VECTOR GRAPHICS offers more possibilities of editing (see there).

Image processing

Image processing > Two-dimensional histogram

This gives an idea about the degree of correlation of two images of the same size (8 bits each). The brightness of the grey values corresponds with the frequency. The highest frequencies can usually be found around the main diagonal. The more culminated and precise they are the stronger is the correlation between the two channels. A further indication gives the correlation coefficient shown in the lower part of the histogram.

Image processing > Rectification

For the orientation or rectification of an image an equation system is set up which enables an assignment between object- and pixel co-ordinates. Concrete: With the help of the control points' co-ordinates and the corresponding pixel co-ordinates, the coefficients a_i and b_i of the equation systems

$x' = a_0+a_1x+a_2y$ $y' = b_0+b_1x+b_2y$ (affine transformation)

resp.

$x' = a_0+a_1x+a_2y+a_3xy+a_4x^2+a_5y^2$ $y' = b_0+b_1x+b_2y+b_3xy+b_4x^2+b_5y^2$ (2nd order polynomials)

are determined. An adjustment using the least squares method will be applied in case of over-determination. In the first case at least 3 points are needed, in the second case at least 6 points. If only 2 control points exist, a similarity transformation is calculated.

In case of over-determination, the residuals (remaining errors) in each point as well as their standard deviation are shown. If a single value shows a strong deviation from the arithmetical mean with sufficient over-determination the transformation should be done without this point. For this use the option (DE)ACTIVATE. The number of this point now is set to the negative value. With a second time marking the point it can be re-activated.

Further methods (without adjustment): Projective transformation (4 points), local / rubber sheet (4 ... 900 points). The latter one is suitable for instance for images with non-regular distortions (like historical maps etc.).

For the calculation of the rectified image there exist different methods for the determination of the colour values ("resampling"), LISA offers the two most important:

NEAREST NEIGHBOUR: Fast, keeps the original colour values, but gives a coarse appearance especially for enlargements.

BILINEAR: A bit slower, smoothes the colour values similar to a mean filter by taken into account a 4 pixel neighbourhood. The result is "nicer" than before but contains additional colour values (mixed pixels).

So, in all cases where the original colour values are of interest for further operations, the first method will be the better. On the other hand, if the optical impression is of higher priority, choose the bilinear resampling.

Image processing > Rectification > Single image

Input: Image and control points file. Method: Move the image with the middle mouse key (or the mouse wheel) pressed until the control point selected in the list below is in position with the measurement mark, then press the left mouse key to save the point data. After a click onto the READY button the rectification will start (see below, NUMERICAL). The orientation parameters are stored in a file named <image name>.`ORI`.

Image processing > Rectification > Image to image

If a geocoded image exists, another image can be rectified to the geocoded one by a direct measurement of reference points. Middle mouse key: Simultaneous movement of both images. Right mouse key: Movement of only the right image. Left mouse key: Registration of points. Method: Move the images with the middle mouse key (or the mouse wheel) pressed until the point of interest is in position with the measurement mark in the left image. Now move the right image with the right mouse key pressed until the respective point is in position with the measurement mark in the right image, then press the left mouse key to save the point data. After a click onto the READY button the rectification will start (see below, NUMERICAL).

Image processing > Rectification > Corner co-ordinates

After input, the image will be rectified (see below, NUMERICAL).

Image processing > Rectification > Numerical

For the rectification of an image, a special control point file is used containing the values [Point No., x, y, row, column] of each point. Such a file named `GEOCOD_R.DAT` will be created from all of the methods mentioned above. Example:

```
        1 32489700.000  6071025.000      702.000      969.000
        2 32498100.000  6052275.000      829.000     1171.000
        3 32504700.000  6037275.000      902.000     1328.000
        4 32528100.000  6072225.000     1143.000      990.000
       ...
32422730.209 32544204.406                          co-ordinate frame in x
 6000748.517  6163394.639                          co-ordinate frame in y
```

The co-ordinate frame for the output image is to be set – the option PROJECT LIMITS will use the values from the project definition.

Note: All transformation methods described above lead in a mathematical view to a transformation of one plane to a second plane parallel to it. For the rectification of aerial images better use the option ortho image in LISA FOTO.

Image processing > Rectification > Adapt

Only for geocoded images and DTMs. The selected image will be adapted to the geometry of the actual project (see FILE > PROJECT DEFINITION): The image content will be limited to the co-ordinate frame of the project, the geometric resolution (pixel size) will be re-calculated to those of the project, and in case of a DTM the height resolution will be adapted.

Image processing > Mosaic

For up to 5 rectified (geo-coded) images or DTMs. In overlapping areas the colour values can be overwritten or averaged.

It is possible to use in the first input field (Image 1) "wild cards". For example, if Image 1 = `TEST*.IMA`, then the files `TEST1.IMA`, `TEST2.IMA` etc. are used for the mosaic. This option is limited to 100 images.

For large mosaics consisting of very many images, a data base should be used.

Image processing > Classification

A classification can be carried out in a single image as well as parallel in several channels belonging together. The necessary parameters can be assigned via an unsupervised classification (cluster analysis) or a supervised classification (analysis of training areas). For the assignment of pixel values to classes, the methods quader and minimum distance are available.

A maximum of five channels (8-bits-images of different spectral ranges, e.g. red, green, blue, near infrared) can be classified at the same time and a maximum of 50 classes (land use, e.g. forest, meadow, water) can be differentiated.

Cluster analysis (un-supervised classification)

Enter the maximum variance of the grey values in the cluster, the maximum number of classes and the names of the individual channels. The programme will search for local accumulations of grey values (one channel) or grey value combinations (several channels), the so-called clusters. The results are stored in the file `ANALYSIS.DAT`.

Supervised classification

This method is basing on the analysis of so-called training areas. These are areas of unique landuse, for instance meadow, wood or water. Within each area the grey values ought to be as homogeneous as possible and typical for the respective use; the size should contain at least 200 ... 300 pixels.

Load one of the possible channels into the display module. Click one by one into the middle of each training area and key in the variance of the grey values (maximum difference to the clicked pixel). In a neighbourhood of ± 20 pixels the grey values are analysed. After the last training area press the right mouse button. Now you can enter further channels which you like to use for classification (max. 4). The results of the analysis are stored in the file `ANALYSIS.DAT`, the images display will be closed.

Define method, start classification

After each of the two described ways the option IMAGE PROCESSING > CLASSIFICATION > METHOD will be started. Select the method (BOX or MINIMUM DISTANCE). The parameters from the file `ANALYSIS.DAT` used for the classification depend on the method:

BOX: For each class and channel the limits from ... to of the grey value range (= edge lengths of the n-dimensional box).

MINIMUM DISTANCE: Largest allowed distance from the centre and medium grey value for each class and channel (= radius and central point vector of the n-dimensional sphere).

Example of the file `ANALYSIS.DAT`:

```
C:\lisa_d\test\DUES4.IMA
   1   8  16  10  12   504   711       501
C:\lisa_d\test\DUES4.IMA
   2 101 111 106  10   723   741       269

   ...
```

Each first line: Name of the channel.
Each second line: Class, minimal and maximal grey value, arithmetic mean, spreading, clicked position (row, column) and number of pixels of the training area.

If needed, the result can be processed with the modal filter (see DISPLAY RASTER IMAGE > RADIOMETRY > FILTER1). Here a more homogeneous appearance is reached.

Finally, the colours can be modified in the image display (DISPLAY RASTER IMAGE > PALETTE > INDIVIDUAL).

Note: As a rule a classification is practised on the basic of original data! Radiometric pre-processing (e.g. stretching of contrasts) shows no additional information but, similar to geometric pre-processing, may lead to a loss of information (mixed pixel values with average filter or rectification with bilinear resampling).

Image processing > Matching

In contrary to the combination of images as mosaic (see above), with matching the images are overlaid and the colour values of the output image calculated from the corresponding pixels. For this, the images must have the same dimension (No. of rows and columns).

The chosen method is done pixel for pixel, for example addition: Colour value of the output image = colour value image 1 + colour value image 2.

Note 1: The entering of a third image is only necessary for some options (see below).

Note 2: For more sophisticated matching (e.g. with more than two input images or using free-definable formulas) see the option ANALYSIS > FORMULA CALCULATION.

The different possibilities in detail:

Addition

- Clipping at white: Sum colour values are limited to the value 255 (white).
- Scaled sum: The resulting colour values are transformed linearly onto the range 0 ... 255. Options: Either the actual value range between the minimum and the maximum or the theoretical possible value range (0 ... 510) will be transformed. The latter case corresponds to the arithmetic mean.
- Weighted addition: "Double exposure". The weight of image 1 can be set between 1 and 99%, image 2 will be weighted with the difference of this value to 100%. See also OTHERS > 2 X 8 BIT → 24 BIT.
- To gap (image1 = 0): Only where no information is given in the first image (colour value = 0) the colour values will be taken over from the second image, either those from the first image will be used.

Subtraction, masks

Remark: A binary image is called a mask. It may be used to cut specific content off other images (see the last two options below).

- Clipping at black: Different colour values are limited to the value 0 (black).
- Scaled difference: The resulting colour values are transformed linearly onto the range 0 ... 255. Options are the same as in the addition.
- Absolute sum from image 1 – image 2.
- Image 2 as mask, remains maintained: Wherever there is a colour value higher than 0 in image 2, the point will be left blank in the output image (set to 0). Otherwise the colour value from image 1 will be taken over.
- Image 2 as mask, remains away: Exactly the other way round.

Division, ratio

- Arcus tangens of image 1 / image 2, increased to mean colour value.
- Scaled quotient: The resulting colour values are transformed linear onto the range 0 ... 255. The quotient can be limited to a maximum value.
- Vegetation (NDVI): e.g. for LandSat-TM bands 3 and 4; as formula: (image 2 - image1)/(image 2 + image 1) with image 1 represents the visible red and image 2 represents the near infrared.
- Snow / NDSI: Like before, but image 1 visible green, image 2 middle IR.
- Moisture / NDMI: Like before, but image 1 near IR, image 2 middle IR.

Others

- Minimum, maximum: The minimum or the maximum value from the colour values of the two input images is used pixel-wise as output colour value. Note: The arithmetic mean can be derived with the addition (see above, scaled sum).
- Directed cosine: Is calculated as quotient of the colour values of a channel to the radiometric distance of the respective point from zero (colour value = 0). The individual channels and the selected channel are to be entered.
- Colour composite: From three channels (raster images of 8 bit each) a 24-bits colour image is generated. To aim for a good optical impression it may be useful to bring the single input channels to their maximum contrast first (in the image display, there RADIOMETRY > HISTOGRAM > STRETCH).
- 2 x 8 Bit → 24 Bit: Similar to the "Double Exposure" (see above) but designed particularly for 8 bit colour images (for instance, coloured height representation plus shaded relief, DTM). The result will be stored as a 24 bit image.
- 2 x 8 Bit → Anaglyph image: Like before, but a "3D image" will be created which may be viewed using red-green glasses. Prerequisite are two images from the same object but taken from slightly different positions (one a bit more from the left, the other a bit more from the right).

Image processing > Area symbols

For the creation of area patterns. The symbol size (number of rows and columns) and the desired colour value are to be entered; moreover, a symbol already existing can be loaded as a draft. An orientation raster appears left on the screen, a test image right. Depending on the selected tool, points can be set or deleted with the left mouse button. You should take into account that with the continued rowing of the symbols a sensible pattern should result – this can be checked in the test image. The finished symbol will be stored with a number between 101 and 200, the extension is SIG.

In the image display, symbols can be used via PALETTE > AREA PATTERN (see there).

Note 1: An image in which the colour values were exchanged by an area dithering is highly suitable for a mathematical matching with a same sized grey- or colour image in the sense of a raster overlay. Then the grey- or colour tones are visible through the area dithering (cf. above, MATCHING > ADDITION > CLIPPING AT WHITE or MATCHING > SUBTRACTION > CLIPPING AT BLACK).

Note 2: See also the option RADIOMETRY > FILTER2 / BINARY > FLOYD-STEINBERG in the image display as an interesting alternative.

Note 3: Self-created symbols (e.g. `101.SIG`) are not stored within the working directory but within the common directory `C:\USERS\PUBLIC\LISA\SIG`.

Terrain models

This module is used for the calculation and analysis of digital terrain models, hereafter simply named DTM. The graphics evaluation (profiles, contours etc.) is available in the image display.

Input data

Almost every type of 3-dimensional co-ordinates can be processed. Usually the aim is to produce and process a *height* model. In order to realise this, a network of well distributed points (= as densely and homogeneously as possible) with the x, y and z (height) co-ordinates being known, is required over the working area.

Note that the quality of a terrain model, which means the extent of an agreement with the real terrain, depends primarily on the density and distribution of the input data (reference points). It is therefore absolutely necessary to take the terrain topography into account while collecting the data. A general rule is: The more undulated the terrain the denser the point network should be. Terrain elements such as edges of steep faces, ridges or V-shaped valley floors should be measured separately and defined as break lines. Local minima and maxima (single points which appear to be higher or lower than their surroundings) have to be entered in the reference point file, too.

The data must be available as vector file; the number of reference points is not limited. The parameter code is used to define the following meanings (see the appendix, vector data).

Example of a border polygon:

```
     9008   -999999.      -999999.         1.
        1      1000.         1000.        10.
        2      1200.         1200.        10.
        3      1050.         1600.        10.
        4      1000.         1000.        10.
      -99       -99.          -99.       -99.
```

… and a starting point for deletion:

```
     4007   -999999.      -999999.         1.
        1      1900.         1900.        10.
```

... this one is located outside the polygon, thus it will be deleted outside.

Important: Border polygons must either be closed, or start and ending point must each be situated outside of the DTM area! Otherwise, the deletion algorithm will "go through a gap" and will delete also other areas. In an extremely case, the whole DTM can be deleted. This is the fact if at the end of the DTM calculation the error message “All grey values equal” (= zero) appears.

Terrain models > Interpolation

Calculates a digital terrain model from the input points as a raster image, scaled to the range 1 ... 32767 ("16" bits, actually for technical reasons 15 bits).

MOVING AVERAGE: Universal, quick method. Best results when reference points are fairly well distributed and densely located. Very suitable for the quick visualisation of an overview and the realisation of major mistakes in the reference point data. Especially close to linear elements (break lines) this method tends to a formation of plateaus.

MOVING SURFACE: Universal method with mostly smooth contour course in flat terrains. Mostly a high accuracy, lower tendency towards a formation of plateaus but also a bit slower. Automatic change between polynomials of 2nd order, tilted plane and horizontal plane. Instead of the automatic switching the method can be fixed to tilted plane for special occasions.

TREND SURFACE: If the number of input points lies between 5 and 900, a trend surface can be calculated through these points. This is a 2nd order polynomial or optional a tilted plane.

Parameters:

The maximum distance from which reference points are to be searched for starting at a new point (search window size) must be entered (in metres).

For the first two methods, the number of reference points which will be searched in each segment for interpolation can be defined between 1 and 10.

A smoothing of the DTM surface may be reached with a mean or Gauss filter of variable window size (standard = 5x5), which is useful, for example, for the generalisation of contour lines. Significant single points (code 4006) as well as “hard” break lines (code 9010) are not touched by this.

Border polygons are closed automatically. In special cases where a border polygon contains several parts and no unified circulation do exist (“spaghettis”), the automatic closing can be turned off.

Terrain models > Filtering

FILL LOCAL MINIMA: Within a selectable window size all pixels which are lower than the border pixels of the window will be set to the minimum border pixel value (filling depressions without runoff).

REMOVE PEAKS: The DTM will be subdivided into tiles of the defined size. In each tile, only the pixel with the lowest grey value will be maintained. From these points, a new DTM will be created by an interpolation with tilted planes. All points of the original DTM which are higher than respective high of the new DTM plus the given threshold, will be eliminated (for instance trees, buildings), the caps then are filled by interpolation.

FILTER: Also after interpolation a DTM can be filtered, optional with a mean, Gauss or self-defined filter with variable window size. See also DISPLAY RASTER IMAGE, there IMAGE RADIOMETRY > FILTER 1 for details concerning the filter matrix.

Terrain models > Contour lines vector

The contours are calculated as a vector file (No., x, y, z). The smoothing of the lines is done via sub-pixel interpolation, the effect of this can be handled in the data reduction running directly after the line calculation: The lower the tolerance value, the lower is the smoothing and the higher the number of output points (see also DISPLAY VECTOR GRAPHICS, there EDIT > THINNING).

Terrain models > Numerical evaluation

In general: All calculations refer to the actual DTM-area. Free cut areas (grey value = 0) from the interpolation are not taken into account in the computation.

TOTAL AREA: Calculates ground and real surface area of the entire DTM. "Ground surface" means the parallel projection onto the x-y-plane and "real surface" the actual three-dimensional surface.

INTERSECTING SURFACE: Calculates the total area of all regions situated on or above a given height.

VOLUME: Calculates the volume between the surface of the terrain model and a reference plain of constant height. The output is done separately for the volume above and below the reference plain. The latter one corresponds to the filling volume.

VOLUME DIFFERENCES: Calculated from a difference-DTM. The output is done separately for volume increase and decrease.

STATISTICS: Relative [%] and absolute areas for heights, inclination and aspects. For heights and inclinations interval sizes are to be given.

Take into consideration the resolution in all computations! The values of x, y, and z in the reference point file from which the DTM was interpolated have to be in the same units. If the values of x and y are in km, for example, and those of z in m, then the result of the volume computation is definitely wrong!

Note: The option VOLUME is only suitable for "true" DTMs, the option VOLUME DIFFERENCES only for difference-DTMs. For the each opposite case the results will be wrong!

Terrain models > Matching > Addition

Add two DTMs of equal position and size.

Terrain models > Matching > Differential DTM

Important: The difference-DTM will only deliver expressive results, e.g. for the calculation of volume changes, if the following conditions are met:

- The pixel sizes, height ranges as well as the co-ordinates of the corners are the same.
- If free cut areas exist, their number and locations must correspond.

Terrain models > Matching > Masking

According to a binary image (mask) of the dimensions like the DTM, all pixel positions with a grey value > 0 will be maintained in the DTM, all others set to 0.

Analysis

Analysis > Formula calculation

One to five input images (8 bits) or DTMs (16 bits) of the same dimension can be flexibly combined according to freely definable formulas (“map algebra”). It is possible to use (combined) brackets. The following syntax must be obeyed when entering the formula:

Operation	Symbol	Syntax
Addition	+	I1+I2
Subtraction	-	I1-I2
Multiplication	*	I1*I2
Division	/	I1/I2
Square root	W	W(I1)
Absolut sum	A	A(I1)
Exponent	E	(I1)E2
Sine	S	S(I1)
Cosine	C	C(I1)

- The image variables have the form In, e.g. I1 for the first and I2 for the second image.
- The formula may have a maximum length of 120 characters.
- The argument for square root, absolute sum and exponent must be in brackets, examples see above.
- In general, the rule "multiplication and division first, then addition and subtraction" is valid as well as the rules for using brackets.

Example 1: I_new = (I1 - I2) / (I1 + I2)
... the result is the vegetation index (NDVI) of a LandSat scene with I1 = channel 4 and I2 = channel 3.

Example 2: I_new = .7*I1 + .3*I2
... the result is a "double exposure" with stronger emphasis on the first image (70 %) compared to the second (30 %).

Note: To avoid algorithmic problems, as argument for square roots, the absolute sum is used all the time. If a division by zero occurs, zero is given as a result. The latter may happen if parts of the input image are without information (colour value = 0).

Analysis > Logical matching (8 bit)

A mask is created by the logical combination of two images. Options:

- Image 1 > 0 AND image 2 > 0 (as well as)
- Image 1 > 0 AND/OR image 2 > 0
- Image 1 > 0 OR image 2 > 0 (either or, XOR)
- Image 1 > 0 AND image 2 = 0
- Image 1 = 0 AND image 2 = 0

Example for the first option: If there is a colour value bigger than 0 in both image1 and image2, the output image shows the colour value 1 at this spot, otherwise the colour value 0. With the help of this mask a special section can be created from an image with the same dimension e.g. in the module IMAGE PROCESSING > MATCHING > SUBTRACTION / MASKS.

Analysis > Statistics 8 bit

Only for 8-bit images. A separate statistic option exists for 16-bit DTMs (see there).

COLOUR VALUE STATISTICS: A file is created which contains the following data concerning the colour values of the determined image: Minimum, maximum, mean, standard deviance, minimum > 0, mean > 0, standard deviance > 0 (that means without taking the background in consideration), number of pixels altogether, the background elements (colour value = 0).

Moreover for each colour value interval (or for each colour value with the interval size = 1): Total area (if the image was geo-coded, otherwise = number of colour values), area in percent, area in percent as a sum as well as a histogram showing the frequency of all with at least 2% frequency occurring colour values. With limiting the colour value range (from ... to) the referential size (sum of all colour values which is set to 100%) can be changed. Example: The value range 1 ... 255 does not include the background pixels (colour value 0) in the statistics.

STATISTICAL MATCHING: A search (reference) image as well as the image to be analysed are to be entered. Usually the search image contains colour coded areas e.g. from a classification or an area filling (option within vector-raster conversion). For each colour of the search image a statistic will be calculated which lists the frequency of the colour values in the input image.

CROSS TABLE: Starting from a search (referential) image, similar to previous option, for each occurring colour the respective colour values of the input image will be analysed and the following characteristics calculated: Minimum, maximum, mean and the most frequent (=dominance).

Note: The colour values listed in the first column can, by entering a text reference, be replaced by the respective text (maximum 20 characters). Example: Colour value 1 (class 1 of a land use depiction) by “Forest” and so on.

Analysis > Environs analysis (8 bit)

A search pattern image is to be determined. It must contain information on point and/or line formations (targets). Barriers or border polygons, which may occur, are to be entered with the colour value 254. You may obtain such an image for example by a vector raster conversion as binary image for the search pattern and a vector overlay of the barriers with colour value 254 (then saving the image). Contained points with a colour value between 1 and 253 can be used for area filling with help of the option COLOUR LIKE SEARCH PATTERN.

The distance from a search object can be calculated using one of three functions: Linear (standard), square or root. The function can be modified with a factor. For the calculation of the real (euclidic) distance the option LINEAR and a factor of 1 has to be used. The other functions depend on the situation. For example, if the search objects are points of noise, then the intensity of noise with increasing distance can be simulated using the root function. Defaults for the factor: Linear = 1, Square = 0.1, Root = 10.

DISTANCE IMAGE: The distances from the search objects are displayed as coded colour values; the brighter, the shorter the distance. It is possible to determine distance steps; steps = 1 results in a continuous representation. The maximum distance to be taken into consideration can also be defined.

BUFFER ZONES: Like previous option but only the first distance step will be given. The result is a binary image (mask).

THIESSEN POLYGONS: Image of the lines with maximum distance between the individual search objects (only points, no lines!). The result is a binary image, the polygons have the colour value 1.

NEIGHBOURHOODS: Also for this the input image has to contain only points and no lines. The output image is then built up by areas with uniform colour values (starting with 1) which each represent the neighbourhood of a point. These are the coloured areas of the Thiessen polygons.

Data base

General remarks

Geo-coded raster images created with LISA can be stored, sorted in different layers according to their contents and only limited by the storage of the hard disc, in an image archive. The integration will be done at the place defined by the co-ordinates automatically (mosaic function). Moreover any areas within the archive can be exported again as raster images.

An image data base is a directory on a storage medium (e.g. `F:\TEST_ARC.LDB`) structured in one or several layers (subdirectories). Example:

```
F:\TEST_ARC.LDB
               \DTM
               \AERIAL_IMAGE
               \LANDSAT
               \TK50_DIG
```

Each layer (= subdirectory) now is subdivided into storage blocks, the so-called tiles. These are raster images of constant dimensions (4000 rows x 4000 columns) which are created and named automatically when obtaining data.

Hardware aspects

It would be ideal if all data are stored on one single computer (file server) in order to keep them consistent. Then the processed data will be saved in suitable time intervals. For instance, removable hard discs or DVD writing devices can be used for this.

Data base > New

The following parameters are to be entered:

DRIVE. The name of the data base is created from the drive, the project name and the extension _ARC.LDB (example: `TEST_ARC.LDB`).

LAYERS: Between 1 and 900. The number of layers may be altered later.

For each layer: Name (max. 60 characters, e.g. AERIAL_IMAGE) and depths in bits (8, 16 or 24).

First of all, the programme tests if the named drive can be used and the directory does not exist. This as well as the given subdirectories (layers) will then be created. The valid entries for the entire image archive are stored in the file `CATALOG.DAT` in the uppermost data base directory, the valid parameters for the single layers are stored in the respective layer in a file of the name `LAYER.DAT`.

Data base > Layer

For the handling of layers there exist the following options:

ADD: Parameters as above (name, depth [bit]).
DELETE: The subdirectory will be deleted.

After each change, the file `CATALOG.DAT` will be actualised.

Data base > Image import / export

WRITE INTO DB: The desired layer as well as the image which shall be imported must be selected. First of all it is tested if the chosen image corresponds to the archive and layer requirements: it has to be geo-coded, pixel size and bit depth must be correct. Furthermore in case of already existing data you have to determine if they shall remain (= merely filling of gaps), shall be overwritten by the new ones (up-dating) or if old and new ones shall be averaged pixel-wise.

The distribution of raster data onto the tiles as well as the placing of names is done automatically (example for tile names: `50005000.IMA`).

Note: The name of the input file may include wild cards (asterisks). For example, entering `GITT*.IMA` all files like `GITT_11.IMA`, `GITT_12.IMA` etc. will be taken over into the data base step by step (max. 1000 images).

READ FROM DB: From the data base a raster image is created for each layer within the co-ordinate range given in the project definition and stored within the actual working directory (IMA format). The file name is composed from “LDB_” and the layer’s name (example: `LDB_AERIAL_IMAGE.IMA`).

Data base > Overview

It is possible either to question the current data base in the image archive in form of a table (for the entire archive) or graphical (as survey image, for a single layer each).

Display

Display raster image

Input: 8- or 24-bits raster image (format IMA, BMP, JPG, PNG or TIF). 16-bits DTMs are converted to 8 bit internally. Co-ordinates display bottom left in the status line: If the image is geocoded, the values of x and y are displayed, either column and row. At the third position comes the colour value and, if it has a numerical meaning (for instance the terrain height), at the fourth position the respective z value. If 24-bit images are used, the colour intensities (red, green and blue) are shown in the 3rd, 4th and 5th position. If a text reference with the same name as the input image exists, instead of the z value the text belonging to the respective colour value will be displayed (e.g. land use).

File

OPEN, SAVE, SAVE AS, PRINT.

Palette

NORMAL, NEGATIVE, COLOUR 1, COLOUR 2, OPEN, INDIVIDUAL, AREA PATTERN, BRIGHTNESS / CONTRAST, FLOOD.

OPEN: To load an existing palette.
INDIVIDUAL: The colour of each pixel value (0 ... 255, click onto the square) can be adjusted individually, mixing the primary colours red, green and blue (additive mixture). The option CONTINUOUS (symbol ◢) calculates all values between the colours to be provided (from ... to). The option SYSTEM starts the Windows colour mixing option for the actual colour value.
AREA PATTERN: Colour values can be replaced by area patterns. The colour value range and the distance between the lines or points in pixels are to be entered. Instead of area symbols, raster images (e.g. scanned graphics) can be used.
FLOOD: Especially useful for DTMs - the area below the defined grey value will be displayed in a blue colour.

The original palette can be restored using the button RESET.

View

Reduce / Enlarge: With mouse wheel or by setting the percentage value.
Move: With pressed middle mouse key. Further, the image detail displayed in the overview image (see below, ADDITIONALS) can be moved using the left mouse key, then moving the image simultaneously.
Rotate by 90, 180 or 270 degrees, flip left-right or up-down with the right-hand buttons.

OPTIMAL: Maximum zoom factor in order to display the entire image
WINDOW: Defines a part of the image by a window drawn with the mouse.
NEW DRAWING or button RESET: Like when starting the image display

PROFILE: The profile trace is determined by 2 ... 100 points of a vector file which must be defined. Creates a colour value profile over the input image or a height profile (if the image is a DTM). In case of a DTM, optional in each point a lateral profile can be created.

3D-VIEW: Available if the image is geocoded and a DTM with the same ground resolution exists. You can select azimuth, inclination and exaggeration. The result can be stored as new image. As an alternative, from the DTM a wire-frame representation can be calculated.

DTM

If the input image is a 16-bit DTM, additional views can be created:

HEIGHT STEPS: The elevations will be grouped according to the desired equidistance (interval in z-direction), the height range can be limited.

CONTOUR LINES: Optional as count lines (in red, all others in black) or colour-coded. If only a part of the contour lines is to be shown, the area below the lowest contour line can be hatched ("flooded").

SHADING: An illumination with parallel incident rays is simulated. The azimuth (north = 0°, clockwise up to 360°, continuously) as well as the tilt angle (10° = flat up to 80° = steep) are to be defined.

ASPECTS: The aspects N, NE, E, SE, S, SW, W, NW and "not tilted" are represented in different colours.

VISIBILITY: You need a vector file with target points which must be located within the DTM area and above the terrain. For instance, this might be radio antenna positions, and the question is if there are areas which will not be reached, caused by the terrain. A radius must be defined (e.g. the maximum distance of the emitter). The programme creates an image showing all areas with free sight to the targets in a dithered representation, colour coded in respect to the distance.

Measure

REGISTRATION: For registering of co-ordinates in the terrain system. For a maximum of 2000000 points.

The registration of data is carried out point after point via pressing the left mouse key. With the right mouse key the co-ordinates of an already digitised point (e.g. on a polyline) is to be caught. Further options offer the buttons CLOSE, INTERRUPT LINE and DELETE.

Note: If you would like to collect data for digital terrain models, please note that the codes are relevant. Contour lines should be digitised with the code 9009 (soft break line).

Which kind of co-ordinates will be registered, results from the kind of loaded image:

- The image is geo-coded: Object co-ordinates will be given as an output.
- The image is not geo-coded, no orientation was done: Column and row positions (pixel co-ordinates) are given as an output.
- The image is not geo-coded but an orientation took place before: Object co-ordinates calculated by a transformation will be given as an output.
- For a DTM, the z-value is the height, else z = 0.

AREA / PERIMETER: Areas of any shape may be surrounded (measurement of points with left mouse key); after pressing the right mouse key the area will be displayed. For each area a minimum of 3 points has to be measured. The result is issued with suitable units (m^2, acres, km^2, resp. m or km). Results of additional measurements may be added or subtracted.

SLOPES / DISTANCES: Two points are to be digitised and their respective height is to be entered. From the measured co-ordinates and the height values the programme calculates the slope inclination in degrees and % as well as the horizontal and spatial distance between the two points in the terrain unit (metres).

POLYLINE: All points of a polyline are digitised one after another; the last one is clicked on with the right mouse key. The total length in the terrain unit (metres) will be shown.

ANALYSIS of the grey values within a polygon (see option CLASSIFICATION; 8 bits)

Overlay

VECTOR GRAPHICS: The superimposition's colour value may be selected. Individual points may be issued alternatively with the corresponding number or height and with a dot mark (small square).

ATTRIBUTE DATA, PHOTOS / TEXTS: Applies for geo-coded images only! The positions for which information is available are indicated by small squares. Clicking onto such a square induces the display of the relevant data set, image or movie. Before starting further operations or closing the window, the right mouse button is to be pressed once.

Radiometry

STRETCH HISTOGRAM: Improves the contrast by linear stretching.
HISTOGRAM EQUALISATION: Improves the contrast by creating a standard distribution of colour values.

Filter 1 (Colours)

MEAN (blur, a low pass filter): Forming of the arithmetical mean. The filter works by smoothing and gives a less sharp image comparing with the input.

EDGE PRESERVING SMOOTHING: Has the same effect as a mean filter, provided that the contrast (difference between the maximum and minimum colour value in the window) does not exceed the chosen THRESHOLD value. Therefore the output image appears less blurred compared with a simple mean filter.

MEDIAN: For the elimination of disturbed pixels (peaks). Assign the mean of the colour values of the neighbours, which are arranged in a rising order, to the central element.

MODAL (MAJORITY): If the colour value with the maximum frequency reaches the indicated least frequency within the neighbours, the central pixel will also get this value. Suitable for the optical improvement of classification results.

GAUSS: Low pass filter, similar to the mean filter, but the colour values within the window are weighted using the Gaussian density function (normal distribution).

EDGE ENHANCEMENT: The effect of this filter can be set using the parameter SHARPNESS (0.1 … 0.9).

LOCAL CONTRAST: Within the selected window size the contrast is enhanced. The effect can be increased or decreased using the parameter SHARPNESS (0.1 … 0.9).

SELF-DEFINED: The values of the filter matrix, located in a text file with the extension FLT, are to be entered. This for instance consists of 9 values (3 in each row) containing the weight for a 3x3-window (real values also possible). Example:

```
-1  -1  -1
-1  16  -1           (a high-pass filter)
-1  -1  -1
```

The 8 neighbours are each weighed with -1, the central element with 16, the sum is divided by the average value (here: 8) (nomination). If there is a "zero sum filter" (sum of weights = 0) a lifting with the average colour value 127 takes place instead of a nomination.

NEGATIVE IMAGE: Inversion of colour value range 0 ... 255 to 255 ... 0.

Filter 2 (Binary)

SECOND ORDER EQUIDENSITIES (edges): Calculates the colour value difference between the current pixel and the pixels at the bottom and to the right. If this value lies below the chosen threshold value the new colour value will be 1, otherwise 0. Thus, depending on the image contrast and threshold value, edges can be detected.

THRESHOLD BINARISATION: Colour values above the determined threshold value will be set to 1, those below to 0.

FLOYD-STEINBERG: The image is dithered.

EROSION, DILATATION: Starting from a binary image the objects contained in it (points or lines) are modified in such a manner that their border is either reduced (erosion) or broadened (dilatation) by one pixel.

OPEN: Erosion followed by dilatation.
CLOSE: Dilatation followed by erosion.

NEGATIVE OF BINARY IMAGE: Exchanges the values 0 and 1.

Filter 3 (Gradients)

FIRST DERIVATION (gradient): Forms the difference between the colour values of the current pixel and of one of its 8-neighbours, which is determined by the chosen "aspect". The result is a pseudo-relief.

LAPLACE, BLURRED MASK: High pass filter with strong emphasis on the central element (Laplace: four times with regard to 4-neighbours, blurred mask: eight times with regard to 8-neighbours).

SOBEL in x (columns) or y (rows): Linear structures in row or column direction will be worked out with the help of difference forming of the current row (column) to the neighbouring row (column).

MONOTONY: For each of the 8-neighbours it is ascertained whether the difference between its own colour value and the colour value of the central pixel does not exceed the chosen threshold. The number of these neighbours determines the new colour value, which gives information about contrast resp. homogeneity in the 3x3 window.

VARIANCE: The difference between the highest and the lowest colour value in the 3x3 window forms the new colour value.

DYNAMIC: The number of opposite neighbours which exceed the chosen threshold defines the new colour value.

CANNY EDGE DETECTOR: With this method image edges (lines along strong colour value changes) can be detected.

Steps / Parts

STEPS (1^{st} order equidensities): Joins the colour values to groups. The step interval in colour values is to be entered, e.g. 10: The colour values from 0 … 9, 10 … 19 etc. are joined together.

RANGE (from ... to): The colour values situated outside of the interval are set to the value 0. In case of the colour values having a numerical meaning, the interval can also be defined via the corresponding z values. For example 50 … 150: All colour values under 50 or over 150 are set to the value 0. If on the other hand only the values below 20 and above 200 shall remain, and those between 21 and 199 shall be set to zero, define the parameters “from” = 200 and “to” = 20.

FACTOR, SUMMAND: The colour values of the new image are calculated from the colour values of the old one according to the formula CV_new = factor x CV_old + summand. Values outside are clipped (= set to the extreme values 0 or 255).

Others

RESOLUTION: 24 → 8 bits colour (Floyd-Steinberg), 24 --> 8 bits grey, colour layers 3x8 bits, 8 --> 16 bits ("DTM"), 8 → 24 bits. Colour layers: The file names are as the input file but are expanded by _R, _G and _B.

NOISE: This option creates a random noise which will be added to the input image. The amplitude of the noise can be set between 1 and 255.

FADE OUT: The image borders (width in pixels to be set) will be faded out stepless to the selected colour value.

Geometry

Rotate image by 90, 180 or 270 degrees, flip image left-right or up-below.

IMAGE CUTOUT: In a geo-coded image by entering the co-ordinates of the lower left and upper right corner of the segment, in a not geo-coded image by entering the first/last row and first/last column. The pixel size remains unchanged.

CHANGE IMAGE SIZE: It is optional whether you enter a percent value or the desired size of the image in pixel. The output image will then be extended row- and column-wise in contrast to the input image. Take into consideration that the image size is changed by the square of the factor. Resampling method: NEAREST-NEIGHBOUR or BILINEAR (see IMAGE PROCESSING > RECTIFICATION).

Additionals

Display of overview image, histogram and legend (for 8-bit images or DTMs). The overview image features the position of the detail currently displayed.

GRID: For geo-coded images. Grid crosses or -lines can be drawn into the image in selectable distance and can be labelled with their co-ordinate values at the image borders.

COPY: Stores the image within the clipboard for use in other graphics programmes.

INFO IMAGE: Image size, co-ordinate range (if geocoded), focal length, rotation. The button FORMAL creates a “formal” geo-codification.

Display vector graphics

This option can be used for vector files up to 2000000 points. You can choose whether you want the points to be displayed with their numbers and/or with their z values. The points and lines may be coloured according to their z values. In the status bar bottom left the object co-ordinates corresponding to the mouse cursor position are displayed.

File

OPEN, SAVE, SAVE AS, PRINT. When exporting into the raster image formats BMP or JPG, the actual displayed part of the file will be stored.

Palette

NORMAL, NEGATIVE, COLOUR 1, COLOUR 2, OPEN. Only available if the option Z → COLOUR is active.

View

Reduce / enlarge by setting the percent value. Moving with pressed middle mouse key or pressed mouse wheel.

WINDOW: Define the desired part of the graphics by a window drawn with the left mouse button.
NEW DRAWING or button RESET: Display as at start.
3D VIEW: You can select azimuth, inclination and exaggeration.

Edit

PARTS, CALCULATION: The data outside the limits can be taken over into the output file unchanged. A logical AND-connection follows (if x-value in the given range AND y-value in the given range ...) as well as a conversion of the form output value = input value x factor + summand.

CO-ORDINATES: After clicking on a point with the mouse cursor, depending on the kind of point different parameters can be edited:

- Single point: Number, x-, y-, z-value and code.
- Point on a line: It is either possible to change x, y, z for this single point (option POINT) or the code for the entire line (option LINE). Finish the edit mode with the right mouse key.

Note: After clicking the OK button, normally the input window will be closed. If it appears a second time, the reason is that there exists another point at the same location.

POINTS → LINES: Define code (range 5001-9999), then click on point after point with the left mouse key, mark last point with right mouse key.

MOVE: Shift point with the left mouse key to the desired position, then let go of the mouse key. The co-ordinates of the target point will be taken over exactly – ideal for a secure closing of polylines, e.g. for a following area filling. Finish the shifting modus with the right mouse-key. Note: If after shifting of a point the point seems to remain at its old position, this means that there were two or more points.

DELETE: You can choose whether you want to delete single points or entire lines. Click on point(s) with the left mouse key and determine the deletion modus with the right mouse key. If you click on a point (or a line) for the second time it will be restored. Moreover polylines can be separated by a marked point. It is possible to restore this with a repeating click on the point. Further, with the option WINDOW an area can be marked; all points within will be deleted.

Points for deletion are marked with a colour and are not taken over into the output file while storing.

THINNING: For the purpose of thinning polylines, for instance digitised contour lines, using the tunnelling method. A tolerance value has to be provided. Each two neighbouring points determine a straight line. All successive points which fall short of the defined tolerance value won't be taken over into the output file.

Additionals

GRID: Grid crosses or lines in selectable distance can be added to the graphics and labelled at the image borders with their co-ordinate values.

COPY: Stores the graphics within the clipboard for use in other graphics programmes.

INFO GRAPHICS: The number of points in the input file are shown as well as the co-ordinate ranges in x, y and z.

Display text

This is used for the creation, display, processing and printing of an ASCII file (text file, vector data). The text display is started automatically in LISA at some places, for example after calculating statistical data of a DTM.

Display attributes

For display, editing or printing of a DBF file. This has to contain in field 1 the x- and in field 2 the y-value (reference- or anchor-point) for each data set and can for example be generated out of a vector file by the option FILE > EXPORT > DBASE DBF. Limits: A maximum of 50000 data sets with a maximum of 25 fields.

RENAME FIELD: Only the name is changed, the data structure (type, length) remains.

ADD FIELD: You have to enter the field parameters (name, type, length). The field will be appended after the last available one.

DELETE FIELD: All data are removed.

DATA FROM VECTOR FILE: The z-value of a vector file that is to be given will be entered into the chosen field of a DBF file according to their x-y-values. Optionally an assignment between (integer) z-values and assigned texts of a text reference can be chosen for the entry of non-numerical data. For this choose a text field, a vector file of the form No., x, y, z and a text reference of the form z, text.

Example: Choose the text field “land use”, then an output-file can be created by a vector file and a text reference and by a replacement of the z-value:

Vector file	Text reference		Output file (DBF)
1 1100.00 1800.00 10.00	10 lawn	→	1100.00 1800.00 lawn
2 1240.00 1417.00 11.00	11 arable land	→	1240.00 1417.00 arable land
3 1800.00 1510.00 10.00		→	1800.00 1510.00 lawn

DATA FROM RASTER IMAGE: Based on the x-y-values of the DBF file the corresponding z-values will be drawn from a geo-coded raster image and entered into a field to be selected.

AREAS: Required are:

- A raster image (8 bits), containing border polygons of the areas to be calculated with the colour value 1 or 255.
- An attribute file (DBF) which contains for each of these areas an anchor point (x value, y value as first and second field) and a numerical field of a length of 12 digits containing 3 decimals, in which the results shall be written.

The sizes of the areas are calculated and entered into the file.

SELECT DATA: Data sets which contain values in two specific fields and are located within certain defined intervals and further on are suitable for a combination will be separated in an output-file. Example: In case the values located in field 3 are between 100 and 200 AND/OR the values located in field 4 are between 35 and 70 the data set will be taken over. Otherwise nothing will happen. If you want to work only with one criteria you can choose the combination AND and set the interval limits for the second field to maximum values (e.g. –999999. ... 999999.). Possibilities to combine: AND (as well as), OR (exclusively, either or), AND/OR, AND NOT.

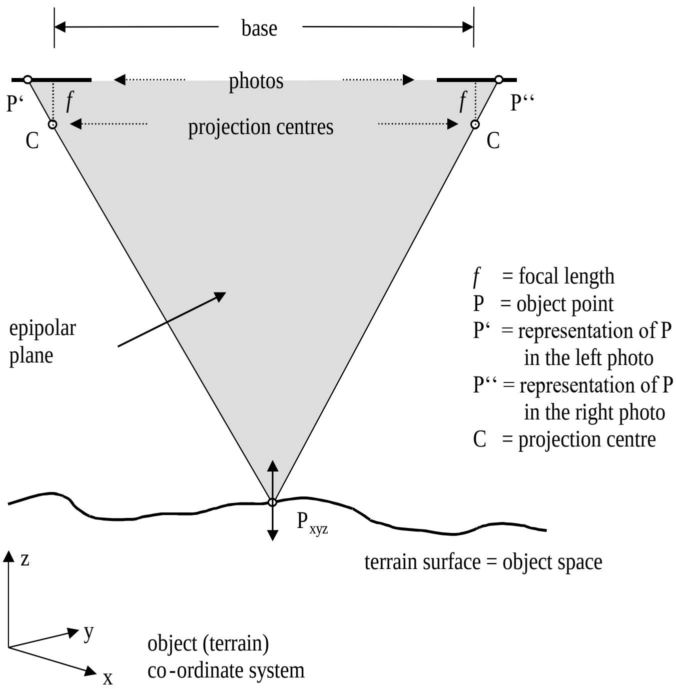
LISA FOTO

General

Principals of functionality

As opposed to many digital stereo workstations (DPWS), FOTO operates not “top - down” (image space → object space) but “bottom - up” (object space → image space).

The orientation of the stereo model in FOTO also differs from customary modes. Instead of the classical division into three parts (interior, relative and absolute orientation) it features an independent orientation for every single image. Therefore it does not comprise a relative orientation – following the interior and exterior (absolute) orientation of every individual image, only a model definition must be carried out for every pair of images.



Way of rays and handling of the image movement in LISA FOTO (here shown for the case of aerial photos): A variation of the position or altitude in the terrain co-ordinate system (object space) triggers a shift of the corresponding image sections.

In all programme parts in which you have to measure within a single image or a stereo model, the principle is “fixed measurement mark(s), floating image(s)” like known from analytical plotters.

Limits

Aerial images: Per block (image set) a maximum of 500 images in up to 20 parallel strips can be handled simultaneously, depending on the programme version. Image co-ordinate measurement: Max. 900 points per model, max. 2000000 points total.

Scanning of analogue aerial images

The following remarks are only valid for analogue photo material (film or paper). Images from digital cameras should only be imported into the LISA format (IMA).

Standard aerial photos taken with a metric camera, usually sized 23 x 23 cm (9 x 9 inch), may be processed. They have to be scanned completely, including the fiducial marks. The (geometrical) scan resolution reflects on the maximum accuracy to achieve and should generally be not lower than 300 dpi or higher than 1200 dpi. The conversion from dpi to pixel size is based on the formula: pixel size in [µm] = 25400 / resolution in [dpi].

The table below illustrates the relation between scan resolution in [dpi] or [µm], the image size in MB (grey scale / 8 bit), the scale and the ensuing pixel size in terrain units at an image format of 23 x 23 cm:

Resolution [dpi]	150	300	600	1200	
Resolution [µm]	169,33	84,67	42,33	21,17	
Image size ca. [MB]	2	8	32	128	(grey values, 8 bits)
Image scale					
1: 5000	0,847 m	0,423 m	0,212 m	0,106 m	
1:10000	1,693 m	0,847 m	0,423 m	0,212 m	
1:15000	2,540 m	1,270 m	0,635 m	0,317 m	
1:20000	3,386 m	1,693 m	0,846 m	0,424 m	
1:25000	4,233 m	2,117 m	1,058 m	0,529 m	
1:30000	5,080 m	2,540 m	1,270 m	0,634 m	
1:40000	6,772 m	3,386 m	1,693 m	0,846 m	
1:50000	8,466 m	4,234 m	2,116 m	1,059 m	

Pixel size in terrain units = ground resolution

Some remarks:

- If at all possible the master film material should serve for scan sources. If the detour of using prints is inevitable they should be processed on plain (non-textured) paper.
- If a simple DTP scanner is used, please take into account that the geometric accuracy of this equipment is more or less 30 … 50 µm, as several surveys have shown. For this, it makes few sense to work with more than 600 dpi (about 42 µm)!
- Please note that the whole aerial photo must be scanned - especially the fiducial marks must be included. On the other hand, the photo border (usually black; contains additional information like image counter etc.) should not be scanned!
- Image names: As a general rule, the image names should be identical with the image numbers (maximum 6 digits) with no other or further text. Example: Image No. 137 will be stored, depending on the format, under the name `137.BMP`, `137.TIF` or similar, but not as `LEFT.BMP`, `FOTO_137.BMP` or else.
- Some general remarks for scanning: Switch on the scanner without a photo on the glass plate! Let the equipment run 5 minutes to get warm. After that, put the photo onto the glass plate and cover the unused area of the plate with a black pasteboard. In this way, the radiometric self-calibration of the scanner is supported.

Buttons in the graphics windows

Size of the display:

- Reduce
- Normal size, 1 image pixel = 1 screen pixel
- Enlarge
- Centre

Form of the measuring mark(s):

- Point
- Cross
- Cross diagonal
- Circle with centre point

Colour and size of the measuring marks can be changed.

Measure, register:

- Create sketch
- Distance
- Angle
- Centre and radius of circle
- Polyline
- Go to position
- Correlation coefficient
- Z value unknown
- Go back by one point
- Close polyline
- Interrupt line
- Go to overnext point
- Delete point

Others:

- Ready
- Cancel

File

Select project, Define project, Edit project

See respective options in LISA BASIC.

File > Import

The input images must be 8- or 24-bit files in one of the formats BMP, JPG, PNG or TIF and should then be imported to the IMA format using this option. Consequently all images of the working directory or all selected ones (press the Ctrl key in the file manager) will be converted to the LISA internal IMA format (batch mode). The file names are numerical; for instance, the image `TEST137A.JPG` will be converted to `137.IMA`. Options:

- ROTATE by 90, 180 or 270 degrees.
- If the images coming from different cameras, they can be connected to the respective camera. The image numbers then have 6 digits, e.g. `100137.IMA` (camera 1) or `200137.IMA` (camera 2). This option is only used for image sequences.

Remarks:

It is possible to work in LISA directly with the formats BMP, JPG, PNG or TIF. Nevertheless, we recommend converting the images into the IMA format with the option described here.

For the photogrammetric evaluation, the image files must have numerical names (maximum 6 digits)! Usually, these correspond with the respective image number. Names like `IMG_1022.JPG` are not allowed, the file should be renamed to `1022.JPG`. Within the import this is done automatically, see above.

Before going on with processing, the calibration parameters should be determined if possible. See the option PRE PROGRAMMES > ORIENTATION MEASUREMENT, then MEASURE > CALIBRATION PATTERN.

Please note: The file extensions for LISA are JPG (not JPEG) and TIF (not TIFF).

Pre programmes

Pre programmes > Camera definition > Analogue

Preliminary remark: The option discussed here is to be applied in connection with conventional (aerial) photo cameras, providing the original photos were digitised by scanning. After the camera definition for each image an interior orientation has to be carried out (see below). In case the source is provided by a digital camera, the option following next is the relevant one; no measurement of the interior orientation is necessary then.

For the interior orientation at least four fiducial marks and the focal length are required. The nominal co-ordinates of the fiducial marks and the focal length, all in millimetres, must be provided – see the calibration certificate of the camera, or use standard values for Zeiss-RMK- or Wild-RC-cameras.

The button CALIBRATION DATA opens another window, giving you possibilities to take the radial-symmetric lens distortion and the image principal point (PPS) into account:

- According to the formula $R * (K1 * R^2 + K2 * R^4 + K3 * R^6)$ (approach of BROWN)
- According to the formula $K1 + K2 * R + K3 * R^2 + K4 * R^3$ (LISA internal)
- Use of distortion values from BLUH (file `SYSIM1.DAT`)
- Data from a table

Example for a table with distortion values:

```
0.0   0.000                 each line: radius [mm], distortion [mm]
1.0   0.007
2.0   0.013
3.0   0.020
4.0   0.026                 (etc.)
```

A click onto the OK button stores the selected parameters. If no distortion correction should be used, click onto the RESET button.

The specifications will be stored in a file having a CMR extension in `C:\USERS\PUBLIC\LISA\CMR`. Example:

```
  1  113.000    0.000                                fiducial mark 1, nominal value x, y in [mm]
  2    0.000 -113.000                                fiducial mark 2, ...
  3 -113.000    0.000                                ...
  4    0.000  113.000                                ...
 153.000                                             focal length [mm]
DP   -0.9999990000E+00    0.0000000000E+00           distortion parameters
DP    0.0000000000E+00    0.0000000000E+00
PP    0.0000000000E+00    0.0000000000E+00           principal point
CS  10.000  10.000     160                           pixel size, diagonal
```

If calibration data were used, additional the figure `CALIB_1.IMA` is created showing the graph of the distortion function.

Pre programmes > Camera definition > Digital

Define the following parameters: Number of columns and rows of the sensor (landscape format, the bigger value = x!), pixel size in [µm] and the focal length in [mm]. If the pixel size is unknown, it can be calculated from the chip size in inch (e.g. 1/2.7”) or mm (e.g. 36 x 24). Or use a search engine and give in the name of your camera as well as the keyword “pixel pitch”.

The programme creates two files, one defining the camera as previously described (file extension CMR), the other being universally valid displaying the parameters of the interior orientation. The latter has the same name as the camera definition file but the extension INN. The interior orientation process for each individual image described below is not necessary in this case.

For distortion correction see PRE PROGRAMMES > CAMERA DEFINITION > ANALOGUE.

Remarks to the images:

- For LISA, always and only use the original images created by the camera.
- If you want to rotate the images, do this only with LISA and not before with another software! This is important, for instance to make sure that calibration parameters are turned simultaneously.

Pre programmes > Control points

For creating or editing a control points file. Such a file is necessary for example if the exterior orientation should be defined by the measurement of at least four points per image. Aerial triangulation also requires a control points. For a maximum of 900 points.

Remark: In contrast to two-dimensional orientations and image rectifications like in LISA BASIC, in photogrammetry these options work three-dimensionally. For that, three-dimensional point co-ordinates (with z values) are necessary here!

Pre programmes > Strip definition

Many options like the automatic measurement of image co-ordinates for aerial triangulation (AATM) need information about the strips in the block. For each strip, the number of the first and the last image has to be defined; these numbers may have between 1 and 6 decimal digits.

The number of strips which can be defined here is limited to 20.

Example for the output file `STRIP.DAT`:

```
0       134 0       140   1   0.0000
0       155 0       161   1   0.0000
0       170 0       164   1   0.0000
```

(The format of this file is compatible to the programme BLOR).

Pre programmes > Orientation > Measure > Interior Orientation

This option is only necessary for scanned analogue images!

Important: To begin with take notice of the fiducial marks' position in relation to each other, respectively in relation to the side information bar. Example: If fiducial mark 1 is, according to the calibration certificate, placed in the middle of the left margin, this will relate to the original photo. Depending on the way the photo was placed on the scanner, fiducial mark 1 might appear rotated by 90 degrees in the digital image, thus be positioned in the middle of the top end margin. This must be taken into account in the camera definition (see above)!

For every image to be processed, an interior orientation has to be carried out previously. The fiducial marks established in the camera definition will automatically and successively be pre-positioned to their approximate values. The centre of each fiducial mark in question must be brought in line with the measuring mark using the middle mouse button depressed (or the CTRL key or the arrow keys); to digitise the position finally click onto the left mouse button. Note: If the fiducial marks (usually little white dots) are hard to identify, it might be helpful to optimise the display using the brightness / contrast regulators. Points which cannot be measured can be skipped by clicking onto the right mouse button.

The option CENTRE FMS activates an automatic centring. Therefore it suffices to hit the mark "more or less". This procedure may however only be applied in connection with point-shaped white marks! Alternatively, choose a rather great enlargement, then measure the fiducial marks manually as exact as possible, disregarding this option.

For more than three fiducials a least squares adjustment is performed and the residuals in [mm] are displayed. This allows extreme values (peaks) to be marked and deleted from the calculation and fiducials to be measured anew. Finally click onto the READY button – this will save the ascertained parameters.

For control, the calculated scan resolution in [dpi] as well as in [µm] will be displayed. If these values differ significantly from the real ones (chosen for scanning) the fiducial mark's nominal co-ordinates may be wrong.

The results will be saved in a file, carrying the same name as the image file but the extension INN. Example:

`  0.1404250000E+04    0.1181858407E+02`	transformation parameters
` -0.9734513274E-01    0.0000000000E+00`	...
`  0.1399000000E+04    0.9734513274E-01`	...
`  0.1175221239E+02    0.0000000000E+00`	...
`  1      2740.000     1410.000`	fiducial mark 1, pixel co-ordinates
`  2      1415.000       71.000`	fiducial mark 2, ...
`  3        69.000     1388.000`	...
`  4      1393.000     2727.000`	...
`RMK_1523.CMR`	camera definition file
`  153.000`	focal length [mm]

The transformation parameters refer to the transition from pixel to image co-ordinates.

Pre programmes > Orientation > Measure > Exterior Orientation

If the results of a triangulation with BLUH are available, no exterior orientation needs to be executed – the parameters from the file DAPOR.DAT will be used. In case the parameters of the exterior orientation are known from a previous measurement they can be used (else click the RESET button).

For each control point the following steps are necessary:

- Select (mark) the point which shall be measured in the list below.
- Adjust the point by shifting the image with the central mouse button depressed or CTRL or the arrow keys until the point and the measuring mark are precisely aligned one over the other.
- Digitising (by clicking with the left mouse button). The point and its number will be displayed in the image and marked with “M” in the listing below.

Note: It is a good idea to start with three or four well distributed, non-collinear points near to the image corners, in this way helping the orientation algorithm to converge.

To make it easier finding a point, optionally a neighbourhood of 121 x 121 pixels of the point can be stored. Choosing the option POINT SKETCHES, the image part will be stored as a small image file. The file name has the form <point number>.QLK. If such a file already exists for a selected point, it will be displayed during the point measurement.

More than four control points produce an over-determination. A least squares adjustment and an indication of residuals with the option to mark and to delete points falling out of the defined limits will be carried out (button (DE)ACTIVATE). As a rule, delete as few points as possible and take care of an equal distribution of the points in the image. After four measured control points, any further point now will be pre-positioned in its approximate position.

Finally click the READY button. The results will be saved in a file, carrying the same name as the image file but the extension ABS. Example:

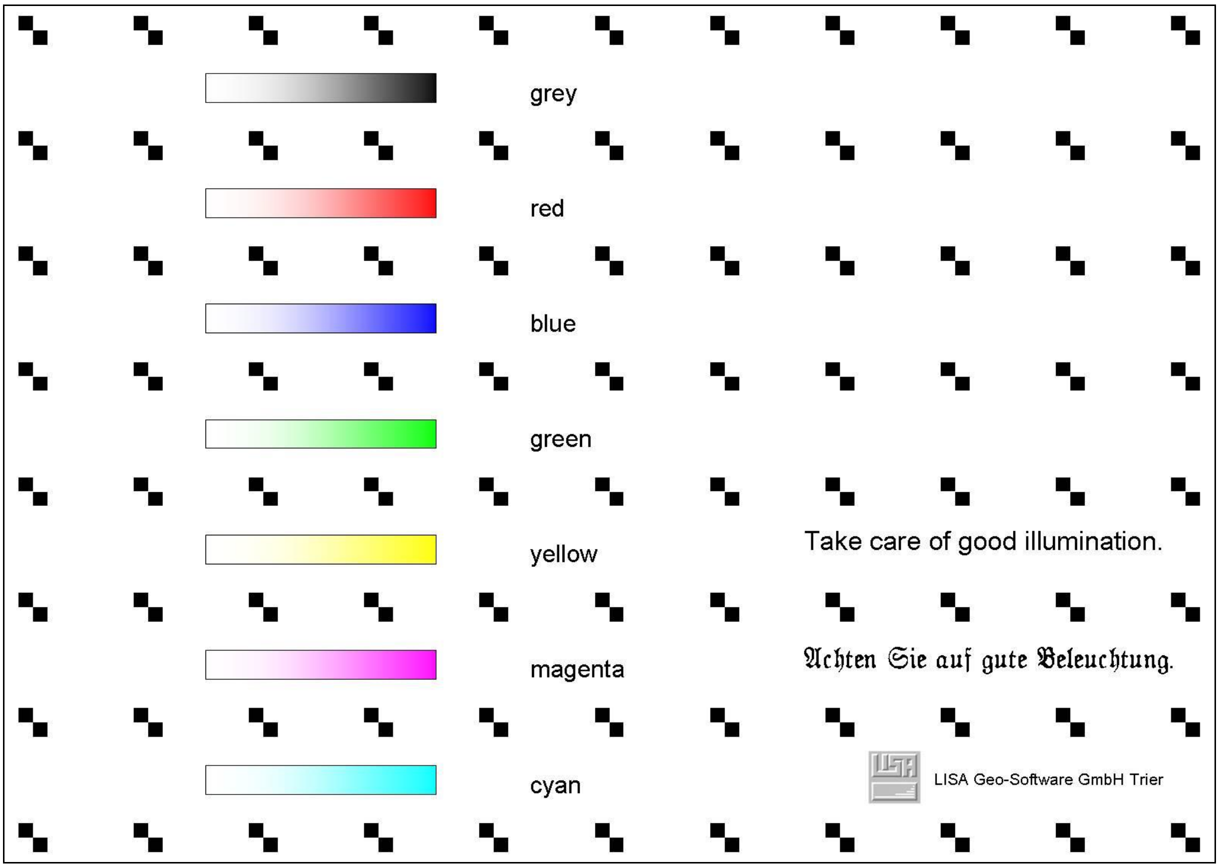
```
   153.000                                              focal length [mm]
      .008        .006      1.587                       phi, omega, kappa [radians]
1136701.547  970322.348   5289.731                      X0, Y0, Z0 [m]
    120011    -108.016     70.005  2548514.900  5689958.100     38.200
    120072     -96.000     -8.455  2548720.500  5688872.700     41.600
    120122     -69.805    -66.654  2549108.300  5688075.100     31.200
       ...
       ...                        (...image- and object co-ordinates of all measured points)
       ...
```

To control the results, please note the following:

- In case of aerial (vertical) images, the absolute values of φ and ω are usually less than 1.
- κ shows the flight direction – east having the value 0 and the angle is being issued counter-clockwise rotating, so representing north as ca. 1.57, west as ca. 3.14, south as ca. 4.71.
- The height of the projection centre (Z0) is the sum of the terrain- and the flight height.
- The standard deviation of the residuals at the control points should not be more than one pixel. The pixel size results from the photo scale and the scan resolution (see table in chapter Scanning of analogue images) or was defined within the camera definition (digital) as pixel size of the sensor.

Pre programmes > Orientation > Measure > Calibration pattern

Option for the calculation of lens distortion and principal point. Use for this our calibration pattern:



Display the calibration pattern on a sufficiently large flatscreen in full-image mode, for instance with the Windows image display. Now take a photo from the calibration pattern in the way that it nearly fills the whole image format (landscape format!). Make sure that all of the target marks are within the image. Also take care of a good illumination and a steady hand. Store the image with a numerical name (e.g. `1000.JPG`).

Now start PRE PROGRAMMES > ORIENTATION, select the image from before and then go to MEASURE > CALIBRATION PATTERN. The amount of target marks is 11 in x and 8 in y.

The programme starts near to the lower left image corner. Measure the first four target marks manually (lower left, lower right, upper right, upper left). Measure the first mark with special care, because from this position a small part of the image is stored and used as a reference for the following marks. The other marks will be measured automatically. At the end of the measurement, the calculation of the radial-symmetric lens distortion and the principal point starts. The result can be viewed in a graphics called `CALIB_2.IMA`.

The results of the measurement are stored in a file with the name of the camera and the extension CAL. Now start again the option PRE PROGRAMMES > CAMERA DEFINITION > DIGITAL and activate the option CALIBRATION DATA. In the next window, just click onto OK.

Pre programmes > Parameters of the exterior orientation

If the parameters of the exterior orientation are already known, they might be imported. The order of the angles φ, ω, κ during their calculation must be recognised – you may know, that the values of these angles depend on the sequence of their calculation! In LISA and BLUH the order is φ – ω – κ. If the angles were calculated in the order ω – φ – κ, please select the corresponding option.

Input data: Rotation angles in grads (full circle = 400 grads), degrees (full circle = 360 degrees) or radians (full circle = 2π), co-ordinates of the projection centre in [m].

Option ROLL-PITCH-YAW: If data from the exterior orientation were collected during the flight (direct sensor orientation with GPS/IMU), the angles must be converted into the photogrammetric system φ, ω, κ. Input format: Image number, rotation angles (roll, pitch, yaw) in decimal degrees with North = 0 for yaw, projection centre (X0, Y0, Z0) in geographic co-ordinates (sequence longitude, latitude in decimal degrees, height in metres). Example:

```
4   8.981   1.498 173.291   9.874096  53.378387  235.880
5   7.252  -0.152 169.779   9.873602  53.378589  242.190
6   3.805   1.387 166.667   9.873115  53.378815  247.240
```

Pre programmes > Select model

If several models have already been defined (see next option), one of them may be selected here. Otherwise the latest active model will be used automatically. The model currently active is being indicated at the status line and stored in a file called `STEREO__.PRD`.

Pre programmes > Define model

Input parameters: Number of the left and the right image, file with object co-ordinates. The parameters of the exterior orientation are either taken from the file DAPOR.DAT (BLUH) or from the individual ABS files (see ORIENTATION > MEASURE > EXTERIOR ORIENTATION). In the first case, the file DAXYZ.DAT may be used as OBJECT CO-ORDINATES file, in the second case the control points file.

As an option, all models of the block as given in the strip definition (see above) can be operated one by one (batch mode). If the input window already contains data of an existing model, the image numbers can simply be switched using the [<] resp. [>] buttons.

The stereo model comprises two kinds of parallaxes. The x-parallaxes are a result of the relief-induced radial-symmetric displacement and are necessary to determine the heights. Without calibration data there might be parallaxes of some pixels also in y direction, which afterwards might be disturbing during an automatic DTM generation (matching). The programme can minimize the remaining y parallaxes.

The programme calculates the co-ordinate range of the model in x and y. Important: Within the model area there must exist at least one point (from the object co-ordinate file)! If this is not fulfilled, go immediately to the stereo measurement and digitise some well-distributed points. For your information, some additional parameters are displayed:

- The approximate pixel size of the input images in terrain units (geometric resolution): This value can serve as point of reference for the pixel size in the project.
- The ratio distance/base: the higher this value, the less certain is the measurement z values.
- The maximum accuracy to be achieved in z depends on these parameters.

The data will be saved in a file whose name is constituted by the left and the right image number and which carries the extension MOD. Example:

`135 136`	image numbers
`DAPOR.DAT`	file with orientation parameters (*)
`DAXYZ.DAT`	file with object co-ordinates
`1135300.000 1138000.000`	model range, x [m]
`969300.000 971482.000`	model range, y [m]
`0.0045`	relative angle
`1`	parallax correction

(*) If the orientations are taken from ABS files, this line keeps empty.

Aerial triangulation measurement (ATM)

Some pre remarks about the image and point numbers:

Image numbers: All images within the block must have a unique number! Concerning the names of the image files see FILE > IMPORT.

Point numbers: Like before, also object points must have each a unique number! The automatic numbering in the manual or automatic measurement (see there) uses the image numbers and a consecutive index – for example, points within image No. 712 will get the numbers 712001, 712002, 712003 and so on. During the manual measurement of connection points (see there) numbers like 777770001, 777770002 etc. are created. This must be taken into account when numbering the control points! If, for instance, all images of the block have a three digit number, the control points may be named 1001, 1002, 1003 etc. without any conflicts with other object points.

ATM > Manual measurement

With this module image co-ordinates can be measured for the aerial triangulation in BLUH. To do so a camera definition is necessary, furthermore the interior orientation of all images must exist.

Remark: Having good image material, an automatic measurement may be carried out instead (see below). But even then, the option described here has to be used to measure the control points or additional tie points. Per model, a maximum of 900 points can be measured.

Both image numbers and the name of the output file must be provided. If the input window already contains data of an existing model, the image numbers can simply be switched using the < resp. > buttons. As already mentioned above within the exterior orientation, also here exists the option to store neighbourhoods of measured points as point sketches to help finding the exact position within further measurements.

If a file with orientation parameters (`DAPOR.DAT`) exist and a file with ground co-ordinates of object points is entered then the corresponding positions of the points in the left and the right image will be set automatically.

For technical reasons the models of one strip should always be worked on starting on the left proceeding to right. This means that for the first model the left and the neighbouring right image of a strip should be taken, then in the next model the former right becomes the current left image and so on.

Display of the images

The left and the right image of the stereo model can be displayed on the screen in two variations:

- Neighbouring left – right
- Overlaying each other, colour coded following the anaglyph method

Trained users are able to see the first display mode in three dimensions. Less trained users should apply an alternative method, namely observe the situation through red-cyan glasses (red filter on the left side). The shape and colour of the measuring marks, under which the image parts are moved, may be altered using the corresponding buttons. An overview image with a rectangle showing the actual position facilitates the coarse positioning within the model. The image display can be performed in several sizes (zoom); the brightness can be regulated separately for the left and the right image.

Roaming in the model

The mouse executes the movement in x-y-direction; the central mouse button is to be held pressed down. Should any difficulties occur, the CTRL button can be used instead. In addition, for precise positioning the arrow keys may be used, for fast positioning you can move the rectangular mark in the overview image.

The left and the right image are normally linked together. To shift the x- and y-parallax the right mouse button has to be held down. In this case only the right image will be moved. As soon as it is brought in line with the left image (parallaxes moved away), the programme may attempt to maintain the correct junction by permanent correlation while the images are moved: Choose the option CORRELATION.

Point measurement

There are four options to measure image co-ordinates:

- From previous model
- Gruber points
- Individual
- Strip connection

The registration of the image co-ordinates will be carried out with a click onto the left mouse button after the left and the right image part are set to corresponding positions. The options:

FROM PREVIOUS MODEL: Two cases are to be distinguished: (A) Points that have been measured previously in the present model, will be displayed coloured blue in the overview image and cannot be measured anew. Should a point be measured again it must be erased in this model before. (B) For points that have already been measured in the (now) left image of the actual model the programme will estimate considering the side lap, if they may possibly also be present in the right image. If this is the case then the programme will mark these in green in the overview image and will automatically set them in the left image; their position is fixed here (automatic point transfer). Accordingly, just the corresponding position in the right image is to be set manually. This option can and should be used from the second model onwards in the strip. If it is not possible to measure a point, the SKIP button or the F3 key may be used.

GRUBER POINTS: To connect both images, at least 6 well-distributed points of the model have to be measured. From the second model onwards the three ones on the left side have already been measured in the previous model and can therefore be adopted. The default distribution is similar to the “six” on a dice, which means two points on the top, two in the middle and two on the bottom of the model. The programme sets those positions automatically and provides point numbers, which are extracted from an increasing index and the left image’s number. Example: Left image number = 747, then the point numbers will be set to 747001, 747002, 747003, 747004, 747005 and 747006. In the case that a point cannot be measured, the button SKIP may be used or alternatively the F3 key like before.

INDIVIDUAL: After entering its number a point will be checked for in the output file, to find out whether it has already been measured in the left image. If it has, a pre-positioning will be performed in the left image as described above (FROM PREVIOUS MODEL). Otherwise the point is to be adjusted freely in both image parts. If it turns out that the point cannot be measured after entering its number, the SKIP button or the F3 key can be applied again.

STRIP CONNECTION: If you have already measured connection points with the option ATM > MEASURE CONNECTIONS (see below) and created point sketches, these will be pre-positioned approximately and their point sketches will be shown bottom left.

Remarks concerning all measuring modes:

- The button READY terminates the relevant module. Afterwards start one of the MEASURE options to continue the process.
- The MEASURE > END option (or the ESC key) causes the measurements to be stored and the module terminated.

Position and number of each point will be superimposed into both image parts; additionally they will be marked red in the overview image. Pixel co-ordinates are stored with the row co-ordinates being mirrored – the origin therefore lies in the left bottom corner. The first line of each model includes the image number, the focal length, the camera name and the rotation angle of the images. The next lines includes the fiducial marks (co-ordinates of the interior orientation), followed by the values point number, x left, y left, x right, y right for each point which was registered. The end of a model is indicated with –99.

For a further application in BLUH the file is to be exported after the completion of all measurements into the respective format with the help of the option ATM > EXPORT BLUH.

Example for the output file:

```
135000136   153.000 CAMERA_1.CMR                      1   (rotation angle, 1 = 90°)
        1  2735.016  1389.988  2739.972  1410.063
        2  1406.985    54.021  1414.941    71.033          (fiducial marks)
        3    64.970  1376.988    68.940  1388.030
        4  1392.022  2713.022  1393.045  2726.955
   135001  1426.000  2551.000   585.000  2552.000          (connection points)
   135002  1426.000  1417.000   540.000  1417.000
   135003  1426.000   284.000   587.000   272.000
   135004  2500.000  2543.000  1765.000  2560.000
   135005  2598.000  1402.000  1856.000  1402.000
   135006  2620.000   284.000  1842.000   252.000
      -99
```

ATM > Calculate strip images

This option is a pre-requisite for the measurement of connection points like described in the next chapter and especially necessary if the block contains more than one single strip.

The strip definition (see above) must already exist. For each strip of the block a special image is calculated containing the single images in a size of each 800 by 800 pixels side by side in the sequence in which they form the strip. The name of the output image is derived from the number of the first and the last image. Example: First image No. 134, last image No. 140, then the output file has the name `ST_134140.IMA`. For a maximum of 20 strips and 50 images per strip.

ATM > Measure connections

With this option, connections points (tie points) between neighbouring images and strips can be measured, serving as initial values for the manual or automatic measurement (AATM, see next chapter). If you want to use the connection points for the manual image co-ordinate measurement, the option CREATE POINT SKETCHES must be activated!

Load one strip into the upper part of the window, the next strip which has a lateral overlap (side lap) with the first one into the lower part of the window. The strips now can be moved independently with the mouse, middle button depressed, and set to the start or ending position using the buttons |← resp. →|. Now click onto MEASURE and define the name of the output file, default is `TIEPOINT.DAT`. Digitise the first connection point by clicking the left mouse button in all images in which it appears, after that click onto the right mouse button (important to increase the point number!). Always begin in the upper strip! The point will be registered, marked in all images with a small red square and labelled with an increasing number. Now digitise, if necessary after moving the strips, the next point in all images, then press the right mouse button, and so on.

Measured points can be (de-)activated within the point number list. After a click onto the respective button, the point number is set to a negative value. A second click will reset the number to the initial value. Points with negative numbers (de-activated) will not be stored in the output file.

Finish the measurement with the READY button.

Here some additional remarks:

- The control points necessary for aerial triangulation of course must be measured in the original images at highest resolution (ATM > MANUAL MEASUREMENT, see above). However, the connection points measured as described here are only used as initial positions.

- If, as a result of a large number of well distributed control points, a sufficient connection between neighbouring strips is already given, the separate measurement of connection points may be not necessary. It is also possible to measure some connection points only in areas with few control points.

- If the block consists of only one single strip, but the images are of bad quality or very low contrast, you can often get better results from the automatic measurement if you measure some connection points manually.

- The more connection points are located in the block, the more stable the strip connection will be! As a basic rule, each model should have at least one common connection point with each neighbouring strip.

- And of course only those points can be used for connection, which appear in at least two neighbouring images (model) per strip.

Example of the output file:

```
777770001      532.000      697.000       134
777770001      276.000      705.000       135
777770001       38.000      709.000       136
777770001      531.000      182.000       155
777770001      288.000      162.000       156
777770001       16.000      186.000       157
777770002      578.000      688.000       135
777770002      349.000      694.000       136
777770002       86.000      707.000       137
777770002      616.000      158.000       156
777770002      344.000      185.000       157
...
```

First column = internal point number, second column = x value, third column = y value (each times pixel co-ordinates, measured in the 800 by 800 pixel images), fourth column = image number.

ATM > AATM (Automatic measurement)

For the processing of aerial images; if the images are located in different strips, these should be in a parallel arrangement.

The following steps must already be carried out: Camera definition, interior orientation of all images, manual measurement of the connection points as described before (optional) and the manual measurement of the control points. The threshold value for the correlation coefficient, the correlation window size and the number of iterations must be set. The control points files (image and object co-ordinates), the connection points file (optional) as well as the output file has to be defined.

In a more or less regular distribution connecting points will be searched automatically and also transferred into the following model, if possible. This is done using image pyramids to get even better results beginning with a coarse approximation.

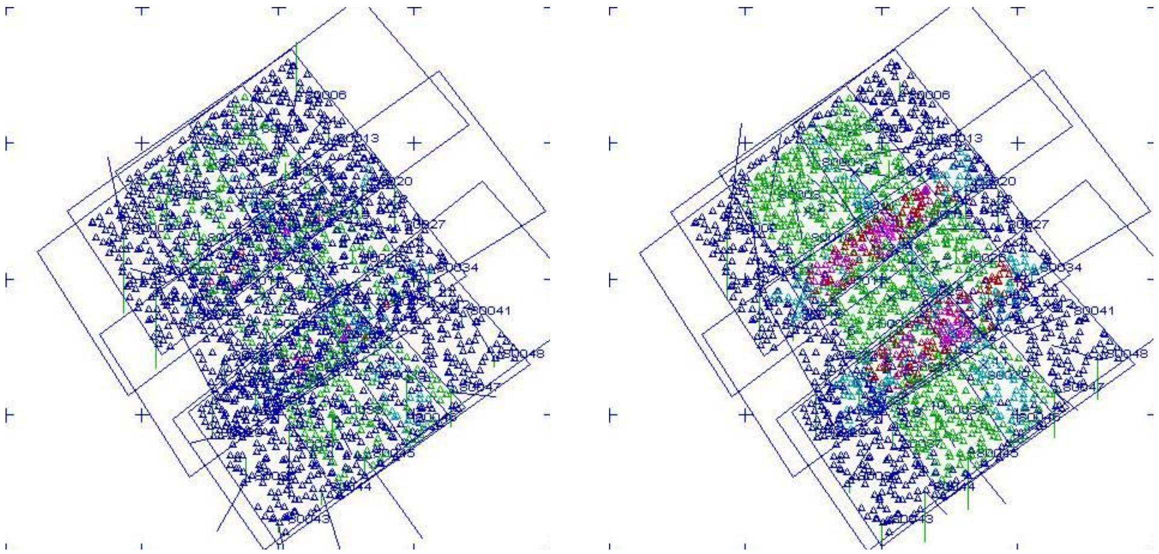
In each image, points are searched within a regular grid of 30 by 30 squares. As a result, the maximum amount of points depends on the longitudinal overlap in % – for example, an overlap of 60% will give a maximum of 60% from 900 points = 540 points. At the beginning, within the squares areas of maximum contrast are searched. Then the homologous point in the right image is determined via correlation. When this work is done in the actual model, a plausibility control is carried out concerning the x and y parallaxes to delete obviously wrong points. After this, a second approach is made using the improved approximations, after that the programme goes on with the next model.

The output file (default name `AATM.DAT`) has the same format as described above (manual Measurement) and contains the pixel co-ordinates of all collected points. This file will be converted into the BLUH format afterwards. Now carry out the block adjustment with BLUH. Use the default names for the output files as suggested: `DAPOR.DAT` (orientations) and `DAXYZ.DAT` (object co-ordinates)!

Usually, the results can be significantly enhanced:

The strip connection was made up to now only with the manually measured connection points and possibly with the control points if these are located in more than one strip. But usually, much more points may be used for this purpose. Therefore start again the option ATM > AATM and select now the option DATA FROM BLUH. Now the programme calculates for each object point the images in which this point shall occur, and establish a much better strip connection, leading to a more stable block. Finally, run BLUH again.

Remark: If, in seldom cases, additional connection points must be measured afterwards using the ATM > MANUAL MEASUREMENT option, the file described before (standard `AATM.DAT`) should be used for output, choosing the option APPEND when the warning message “File already exists” appears. In this case, the export to BLUH must be started afterwards.



Enhanced connection of the images (within each strip: green dots, between neighbouring strips: red dots).

The next step will be PRE PROGRAMMES > MODEL DEFINITION with option ALL activated.

ATM > Export BLUH

Input: File with the pixel co-ordinates from a manual or automatic measurement. The pixel co-ordinates are transformed onto the fiducial marks' nominal co-ordinates of the camera definition, becoming image co-ordinates. Example for the output file DAPHO.DAT:

```
135000136   153.000
  13502      2.778    99.217   -68.507    98.679
  13503      2.238     2.836   -73.106     2.136
  13504      1.698   -93.460   -69.928   -95.321
  13505     93.678    98.093    31.333    98.531
  13506    101.429     1.076    38.225    -0.064
  13507    102.759   -93.954    36.238   -97.904
    -99
```

Note: This option is called automatically at the end of the AATM and so must not be started separately there.

Processing

Processing > Stereo measurement

This module allows object co-ordinates to be measured in an orientated stereo model with an optional linked DTM. The camera definition, the orientation of both images as well as the model definition must already exist.

Note: If a DTM does not exist, it is possible to begin with an initial height which should be equivalent to the average object height. However, some of the following options become inapplicable then.

Display of the images

Identical with the display in the module ATM > MANUAL MEASUREMENT (see there).

Roaming in the model

(a) Object space → image space („RRS“, standard case)

The mouse executes the movement in x-y-direction; the central mouse button is to be held pressed down. Should any difficulties occur, the left and the right mouse button should be pressed down simultaneously OR the CTRL button can be used.

Navigation in z direction (= elimination of the x parallax) is also mouse-controlled (wheel or right mouse button). While navigating over the model either the last fixed height may be maintained or the height of the connected DTM can be adopted permanently (option Z FROM DTM).

The movement of the images is done by changing the x-y-z- co-ordinates in the object space. Using the collinearity equations, the corresponding image positions are calculated from these co-ordinates and the images are positioned to the measurement marks. So, the images are following the mouse movement.

(b) Image space → object space („RVS“)

With the central mouse button pressed down both images are moved, with the right mouse button only the right image (similar as described above, see ATM > MANUAL MEASUREMENT). From the actual image positions then the object co-ordinates are calculated with an intersection in space and displayed in the status line bottom left.

The GO TO button allows a point to be positioned directly by manual input of its terrain co-ordinates. The CENTRE button resets the current position to the centre of the model. The button R = calculates the correlation coefficient in a 25x25 pixel neighbourhood for the current position of the left and the right image.

Modes of measuring

The registration of data is started by the REGISTER option. Three-dimensional terrain co-ordinates can be captured (No., x, y, z). One of three alternative ways may be selected:

- Points / lines: Manual positioning and digitalisation of points and lines. As an option a subsequent pre-positioning is carried out regarding the points of an input file, provided they lie inside of the model range.
- Profile: The pre-positioning will be carried out after entering the starting and the final point as well as the step range (interval).
- Grid: The pre-positioning will be carried out after entering the co-ordinate area and the width of the raster; the defined area will be covered step by step beginning with the lowest x and y value.

Note: Pre-positioning has the effect that the x-y-values of the actual point cannot be changed – only the altitude can be set using the mouse, central wheel or right button depressed.

The digitalisation can be aborted with the CANCEL button. If a pre-positioning takes place and a point cannot be measured stereoscopically there are two alternatives: Using the SKIP button (or F3 key) causes the direct continuation of the process with the next point leaving the one in question unregistered. Alternatively, the Z ? button (or the F4 key) stores the point with a z value of –999999.

OVERLAY > DTM POINTS: This option is useful for example in combination with the STEREO CORRELATION (see next chapter). If the option INTERPOLATION was deactivated and a more or less incomplete DTM created by matching, DTM points which are determined by correlation can be projected into the left and right image. In areas with big gaps, additional points should be measured manually (previous option REGISTER) and subsequently this incomplete DTM and the file containing the additionally measured points should be combined into a complete DTM using the option PROCESSING > DTM INTERPOLATION.

OVERLAY > VECTOR DATA: Projects the content of a vector file to be provided into both images (superimposition). Attention: For the transformation from terrain to pixel co-ordinates the z value from the vector file is used, not the height of an optional loaded DTM.

OVERLAY > NEW DRAWING: This undoes the options above by reading the images anew which might require some time.

And here one more idea: Eventually, you may be uncomfortable to work always with three changing mouse buttons – the central button for moving the model, the wheel or the right to set the elevation and the left to register the co-ordinates. For this, here are two suggestions:

- In any case, make sure to have a DTM, for example using the stereo correlation (see next chapter), and start the stereo measurement with it. Now it is not necessary to set the elevation.

- If you digitise points without a pre-positioning, just keep the CTRL key depressed. With this, the model follows the mouse movement (like you would press the middle mouse button), and you only use the left mouse button for registration.

Single measurements

With the respective buttons you can measure distances, poly lines, angles and circle data (radius / centre).

Processing > Stereo correlation (matching)

The camera definition, the orientations of both images and the model definition must already exist. Only the actual model or all models of the block as given in the strip definition can be processed (batch mode), in the latter case the results will be joined to a mosaic afterwards.

In this module the elevations within the model area will be reconstructed. Because the orientation of each image is known, the programme can calculate corresponding pixel co-ordinates for any terrain point (x, y, z). As mentioned before, the process works "from bottom to top" – proceeding from an initial height z_0 in a given position (x, y), the z value will be modified until the resulting image parts fit ideally ("area based matching"). The criterion for this is the maximum of the correlation coefficient. In this way, a surface model (DTM) is generated.

The maximum displacement in x (px = x parallax) must be provided. Further, a threshold value for the correlation coefficient, the correlation window size and the number of iterations must be defined. A file with object co-ordinates of known points must exist. The following remarks concern the individual parameters:

PX: Usual are values between 2 and 5. The stronger the relief, the higher must be this value. It should nevertheless not be set unnecessarily high to maintain precision and working speed because then wrong correlations may occur, for instance in areas with repetitive structures.

Correlation coefficient “r”: In most cases the suggested value (0.7) can be maintained. Except for particular cases (e.g. low contrast images) it does not make much sense to choose a value of less than 0.6 – this will cause more points to be correlated but also leads to a loss of accuracy.

WINDOW: The greater the window, the more stable will be the results and the more time for calculation will be needed. Small correlation windows may lead to problems in areas with repetitive structures. You may start with a value between 7 and 13.

Filtering of the DTM: Please keep in mind that filtering will modify the height values especially at local minimum and maximum points. When a maximum of precision is of importance it is recommended to work without a filter. On the other hand filters have proven to be successful if for instance subsequently contour lines should be generated on the basic of the DTM.

Note: For the purpose of reassessment it may be advisable to deactivate the (standard) option INTERPOLATION. The resulting DTM will then show gaps of different sizes, especially in areas with little contrast. In these areas points should be measured manually – compare this also with the notes in the chapter PROCESSING > STEREO MEASUREMENT as well as with the following chapter.

Processing > DTM interpolation

In the case that a DTM generated by stereo correlation had shown gaps and therefore additional points were measured manually, an area-covering DTM may be interpolated with the help of this option from the initial DTM and the points measured in addition. The option MODEL LIMITS restricts the interpolation to this area instead of going to the project area borders of the DTM.

Processing > Ortho image

This feature serves the purpose of the differential rectification of a digital image onto an underlying DTM. The rectification quality depends on the quality of the DTM! The images to be processed must be oriented entirely, and a DTM should exist. As an alternative it is possible to rectify to a horizontal plane (z constant).

Three options concerning the input images are available:

- Single image
- Actual model
- All images

ACTUAL MODEL: The model definition must have been carried out already. Then, the left as well as the right image of the current model will being used in a way that those features of the image lying closer to the left image's principal point will be adopted from the left image; analogously on the right hand side (nearest nadir).

ALL IMAGES: Assume that a complete DTM already exists for the whole project area (for example created within the stereo correlation, option ALL MODELS + CREATE MOSAIC used), then with this option all oriented images within the working directory can be rectified and matched in one pass. The programme takes all oriented images from the strip definition and process them one after the other. The colour value definition within the ortho image will be done in the nearest nadir mode.

In case of the second or the third option, a stepless colour value adjustment between the particular images can be selected.

The rectification takes place on the area determined by the DTM or, in case of using a horizontal plane, within the project area. In positions for which no DTM information is available (blank spaces, e.g.), the ortho image remains empty. The geometric resolution (pixel size) of the ortho image is taken from the project definition.

Processing > Image sequence

Pre-remark: This option is designed for automatic processing of image sequences (in this case stereo models photographed in a chronological order). The left image always corresponds with the same camera (position) and so does the right one. The image numbers must have 6 digits – then, the first digit refers to the camera number. Example: Image 100001 was taken from camera 1, image 200001 from camera 2. To make this simple, in the option FILE > IMPORT you can connect selected or all images with chosen camera. By this, the reference to the camera definition files `CAMERA_1.CMR` and `CAMERA_2.CMR` can be handled.

About how to handle this tool: Beginning with the object points of the first model and a stereo correlation is executed. Object points are derived from the resolving DTM in a regular grid to serve as start values for the model definition of the ever next model to follow. Further, using the DTM and the images of the actual model, optionally an ortho image is created.

To make the programme track the images reliably a certain numbering mode (naming) of the image files is inevitable. Example with 10 models, then the image files may have the following names:

Model 1: left image `100001.IMA`, right image `200001.IMA`
Model 2: left image `100002.IMA`, right image `200002.IMA`
...
Model 10: left image `100010.IMA`, right image `200010.IMA`

In other words: All images have an unequivocal number, whereby the image numbers (-names) of the left and of the right camera are chosen in ascending order.

The exterior orientations of the first two images (first model) and the model definition of the first model must already exist.

Input data: Left and right image of the first model, left and right image of the last model. Finally, the input window with the parameters of the stereo correlation appears (see there).

Output:

- DTMs named `GT_`<left image, right image>, e.g. `GT_100001200001.IMA`
- Optionally ortho image named `OR_`<left image, right image>, e.g. `OR_100001200001.IMA`

Display

Display raster image

Similar to the respective option in LISA BASIC.

Display text

See the respective option in LISA BASIC.

BLUH

Pre remarks

The programme system BLUH (bundle block adjustment) is developed and owned by Dr.-Ing. Karsten Jacobsen, University of Hannover, Germany. BLUH is also the necessary addition to LISA FOTO for the aerial triangulation of image blocks with the help of a bundle block adjustment.

In licence, we distribute BLUH in three versions:

- LISA_30 for a maximum of 30 images, limited functionality
- LISA_200 for a maximum of 200 images, no other limitations
- LISA_500 for a maximum of 500 images, no other limitations

For an easier handling in connection with LISA the programme BLUH_WIN was developed which controls the central BLUH modules from a Windows interface. For this, a parameter file called `SYSTEM_BLUH.DAT` is created and after that the selected module is started. The result lists of each module (extension LST, e.g. `BLUH.LST`) are displayed in the text editor after the module has finished.

The following descriptions refer mostly to BLUH_WIN. For more and detailed information about the programme system BLUH please use the descriptions which are delivered together with BLUH.

Pre processing

Pre processing > Select project, Define project

See the respective options in LISA BASIC.

Pre processing > Control point editor

See the respective option in LISA FOTO.

For the aerial triangulation with BLUH, for each control point a factor for the standard deviation in a range between 1 and 9 can be defined. Example: The standard deviation in BLUH was defined as 1 meter for x, y and z. For a control point with problems in x and y, the factor may be set to 5, increasing the standard deviation for this point to 5 meters. For x-y-control points the z-value and the factor for z must be set to 0, for z-control points the x- and y-value as well as the factor for x/y must be set to 0. Example:

```
80001   260834.230  9361733.530      868.000 1.00 1.00    x, y, z used
80002   261034.340  9367396.920      984.000 1.00 1.00
80003   261536.300  9369026.010      977.000 1.00 1.00
80004   261782.380  9369459.460      979.000 1.00 1.00
80005        0.000        0.000     1020.000 0.00 1.00    only z
80006   255501.000  9377104.000        0.000 1.00 0.00    only x, y
```

Pre processing > Strip definition

See the respective option in LISA FOTO.

Pre processing > Photo co-ordinates editor

The data of the input file (usually `DAPHO.DAT`) are displayed in ascending point number order. After marking (clicking onto) a point in the list window, its number may be changed. The single point or all points with the same number can be erased using the respective button. Doing this, the number will initially be set to its negative value; the deletion can therefore be reversed by repeated marking and erasing (the point number will return to its original value).

Using the OK button causes the file to be actualised and stored; points with negative numbers will thereby be deleted.

Block adjustment

Block adjustment > Strategy

This is an option to help beginners setting the parameters. All you must know are some details like the approximate scale and the scan resolution (in case of analogue photos) or the approximate ground resolution and the pixel size of the sensor (in case of digital images) and some more.

Depending on the quality of the photo co-ordinates, the strip connection and the control points, several of the BLUH input parameters are set to useful values. Nevertheless, in the following modules you may change each of those parameters.

Block adjustment: The central BLUH modules

PRE 1 (BLOR), PRE 2 (BLAPP) and MAIN (BLUH): See the respective BLUH manuals, also the description of BLIM (input parameters for the main programme).

BLOR

2D PRE-CHECK: Before starting BLOR, a 2D adjustment can be started to find large errors. Please remove the wrong data, then start PRE 1 (BLOR) again.

Remark: If BLOR will not run properly or with bad results it might be helpful to use the options OBLIQUE PHOTOS > SMALL VIEW ANGLE and TRANSFORMATION > 2D. This will lead to a high stability even with not very good input data. It is also advised to use these options for images taken with a digital consumer camera, for instance operated on micro-drones (UAVs).

AUTOMATIC ERROR CORRECTION: From the file `BLOR.COR`, created in the pre programme BLOR, optionally an error correction list named `DACOR.DAT` can be created and used in the following module BLAPP. Some remarks about this:

We have to divide between errors at control points, tie points of neighbouring strips and other points. The errors are listed in `BLOR.COR` according to their size in relation to the defined standard deviations, then marked with asterisks from no asterisks = small error to 4 asterisks = large error. For each point group can be selected from which amount of asterisks an error correction will be carried out (for instance, errors at control points beginning with ***). Please take into account that any automatic correction is a bit dangerous. If, for example, the limit for all groups of points will be set to the lowest value (*), then it can happen that a lot of points will be ignored in the adjustment what may have a negative influence to the strip connection and the stability of the block. Therefore it is suggested to start with the following limits: CONTROL POINTS ****, TIE POINTS ***, OTHER POINTS *. According to the fact that automatic aerial triangulation measurements (AATM, like those in LISA FOTO) usually will find a large amount of points, the value of the third point group (OTHER POINTS) can be set to a low value in most of these cases.

BLUH

A general remark if you have images coming from a non-calibrated digital camera: Within the main module BLUH you can activate the option USE OF ADDITIONAL PARAMETERS > AUTOMATIC REDUCTION and then select at least parameter 9 (radial-symmetric lens distortion, see the BLIM manual for further details). In the camera definition of LISA FOTO, use the option CALIBRATION DATA and then FROM BLUH, using the data from `SYSIM1.DAT`, see the programme description of LISA FOTO for details. After the distortion values are added to the camera definition file, image co-ordinates from LISA FOTO are corrected by them when you use the option ATM > EXPORT BLUH. For further runs of BLUH it is then no more necessary to use additional parameters.

If you have a block of images with high stability (good overlap within each strip and between the strips, precise and well-distributed control points, precise image co-ordinates) then you can try to adjust the nominal focal length and to calculate the principal point. This can be done with the additional parameters 13 (focal length), 14 and 15 (principal point). In the same way like described for the radial-symmetric lens distortion, you should use then these parameters in LISA FOTO, camera definition (data from SYSIM1.DAT).

Block adjustment > All (batch)

Runs BLOR, BLAPP and BLUH directly one after the other. This option is useful if for instance after a previous run control points, input data or parameters were changed.

Block adjustment > Analysis (BLAN)

See the BLAN manual for details.

A remark concerning the option DISTANCE FOR NEIGHBOURING POINTS: BLAN will include a listing of neighbouring (or identical) points in the output file BLAN.LST, depending on this value. Example:

```
NEIGHBOURED OR IDENTICAL POINTS
===============================

                                      DX       DY       DZ  HOR DIST

          866211          874104    .031   -.073    .047      .079
          866301          874050   -.074    .065    .092      .098
          866355          874137    .084   -.045    .014      .095
          ...             ...
                  MEAN SQUARE       .061    .062    .050          14
```

If you now start again Pre 2 (BLAPP), these points are added to the file DACOR.DAT (see description of the automatic error correction, above) in the following way:

```
          874104          866211         0         0    1
          874050          866301         0         0    1
          874137          866355         0         0    1
          ...             ...
```

If you now run again Main (BLUH), then each of these pairs of point is united which improves the strip connection and the geometric stability of the block.

Display

Display graphics

For the display of plot files from BLAN. These have the format HP-GL-1 and the extension PLT.

Display text

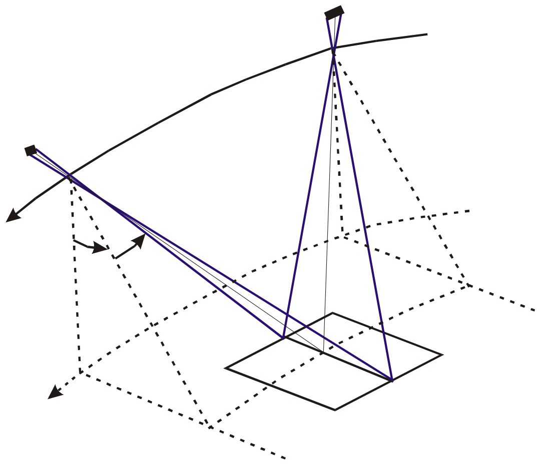
See the respective option in LISA BASIC.

LISA FFSAT

Introduction

The programme LISA FFSAT is a digital photogrammetric workstation for stereo satellite data. The general handling is the same as in LISA FOTO. The differences are results of the different geometry: With FOTO, imagery from central-perspective cameras can be processed. Most cameras operated on satellites are line-scanners, meaning that we have central perspective only within a single line (across the flight direction) but a parallel projection from line to line (in flight direction).

Satellites which collect stereo imagery usually work in the way that one line is “looking forward”, another “looking backward”. Therefore, the “left image” in the traditional photogrammetric sense is created by the looking forward scan line, the “right image” some minutes later by the looking backward scan line.



Geometry of satellite stereo images. From Jacobsen, 2008

From this it is obvious that a classic photogrammetric orientation of such images is impossible. But there is an alternative: Together with each image you can get a list of parameters, the so-called rational polynomial coefficients (RPC). These used in a special algorithm build by polynomials replace the collinearity equations of the traditional photogrammetry, and give an approximate exterior orientation which then must be improved using ground control points:

$$x' = \frac{P_1(x, y, z)}{P_2(x, y, z)} \qquad y' = \frac{P_3(x, y, z)}{P_4(x, y, z)}$$

with $P_n(x, y, z) = a_1 + a_2*y + a_3*x + a_4*z + a_5*y*x + a_6*y*z + a_7*x*z + a_8*y^2 + a_9*x^2 + a_{10}*z^2 + a_{11}*y*x*z + a_{12}*y^3 + a_{13}*y*x^2 + a_{14}*y*z^2 + a_{15}*y^2*x + a_{16}*x^3 + a_{17}*x*z^2 + a_{18}*y^2*z + a_{19}*x^2*z + a_{20}*z^3$

Image co-ordinates calculated from ground co-ordinates using RPCs (a_i). In total, 80 coefficients are used – each 20 for the polynomials P_1 ... P_4).

Image sources

Usually different kinds (levels) of images are offered meaning the way of geometric and radiometric processing and enhancement. Make sure that you have *original* images, sometimes called “RAW”, “level 1” or similar – in other words, images without any geometric rectification. Also make sure that you not only have the images but also the RPC data and some ground control point data for the orientation improvement.

File

Select project, Define project, Edit project

See respective options in LISA BASIC.

Import

FFSAT can only handle 8-bit- resp. 24-bit-images in the IMA format. Import formats are BMP, JPG, TIF or RAW. For images with 16 bits resolution a conversion to 8 bits is done. In addition, a rotation by 90 degrees clockwise is possible.

Pre programmes

Sensor definition

This option replaces the “Camera definition” of LISA FOTO.

The RPC’s mentioned above will give approximate image co-ordinates from points with given geographic ground co-ordinates (x, y, z; x = longitude, y = latitude). Usually all data we process and want to create will be in a Cartesian system like Gauss-Krueger or UTM. They must be transformed internally into longitude / latitude, so please select the system, the ellipsoid, the zone and the zone width. If the images were taken from an area on the southern hemisphere please also select this option.

The results are stored in a file with the name of the sensor and the extension CMR. Example:

```
  1   2
 20  34   6   0
  1
```

First line: Sensor, co-ordinate system (1 = GK, 2 = UTM, 3 = Geographic). Second line: Ellipsoid (20 = WGS 84), zone number, zone width in degrees, southern hemisphere. Third line: Images turned by 90 degrees.

Orientation measurement

Similar to the respective option in LISA FOTO.

As written before, the RPC data gives only an approximate exterior orientation of the images. It is necessary to improve this by the measurement of control points. The advantage is that the RPC approach will lead to a helpful pre-positioning, so you easily can find each control point in the image.

Like in LISA FOTO you can use existing orientation data (or more precise, bias-and-drift improvement data for the orientation given by the RPCs), furthermore you can create point sketches for each control point. For a good improvement at least 4 well-distributed control points are necessary. If you have less than 4 points or if you have selected this option, only a simple shift will be calculated.

The results are stored in a file with the name of the image but the extension ABS. Example:

```
    0.6306896938E+02    0.1000234108E+01    0.4484747673E-03
   -0.3580213963E+02   -0.1995917036E-03    0.1001294288E+01
BANDA_RPC.TXT
```

First line: Coefficients for the bias-and-drift improvement of x. Second line: The same for y. Third line: Name of the file with the RPC data.

Remark 1: The method of improvement (bias-and-drift = affine, or a simple shift) depend on the number and distribution of the available control points, the sensor and other parameters. For instance, with Ikonos data normally a shift will be enough to get good results.

Remark 2: Usually the RPC data files have the extension TXT (Cartosat, Ikonos, GeoEye), RPB (QuickBird) or PVL (OrbView-3).

Processing

Stereo measurement, Stereo correlation, DTM interpolation

See the respective options in LISA FOTO.

Ortho image

See the respective option in LISA FOTO. Unlike there, you can select only one single image for the ortho rectification.

Appendix

LISA file formats

Raster images (.IMA)

The header contains some common data (150 byte), flags (20 byte) and pointers (200 byte) and therefore always has a length of 370 bytes.

(a) Common image data (150 bytes)

Byte	Format	Meaning
1 ... 6	I6	No. of image rows
7 ... 12	I6	No. of image columns
13 ... 14	I2	Bits per pixel (radiometric resolution)
15 ... 29	F15.4	minimum x value (left image border)
30 ... 44	F15.4	maximum x value (right image border)
45 ... 59	F15.4	minimum y value (lower image border)
60 ... 74	F15.4	maximum y value (upper image border)
75 ... 89	F15.4	pixel size (geometric resolution)
90 ... 104	F15.4	minimum z value (DTM: minimum terrain height)
105 ... 119	F15.4	maximum z value (DTM: maximum terrain height)
120 ... 134	F15.4	factor of height scaling
135 ... 144	F10.3	focal length [mm], either 0.
145 ... 150		reserve

(b) 20 flags (20 bytes)

Flag No.	Byte	Format	Meaning
1	151	I1	0 = image, 1 = DTM
2	152	I1	
3	153	I1	rotation angle (n*90)
...	...	...	
20	170	I1	reserve

(c) 20 pointers (200 bytes, give the first byte of the corresponding data set)

Pointer No.	Byte	Format	Data set
1	171 ... 180	I10	begin of palette (0 = no palette, or 371)
2	181 ... 190	I10	begin of image data (371 or 1139)
3	191 ... 200	I10	
...	...	...	
20	361 ... 370	I10	reserve

(d) Palette (only in 8-bit images)

Contain the palette entries. For all grey values (0 ... 255) three entries for red, green and blue exist (intensities, 0 ... 255, format 3I1). Therefore, the palette all times has a size of 768 bytes and is located in byte 371 ... 1138.

(e) Image data

The image data begins in byte 371, if no palette is present, or in byte 1139 else (see also pointer 1 and 2). For true colour images (24 bit) the colour information is stored pixel by pixel (BIP) using the sequence BGR like in the Windows-internal bytemap format.

Vector data (.DAT)

Vector data in LISA consists of three-dimensional point co-ordinates which are stored line-wise in the sequence number, x-value, y-value, z-value.

The notations x, y, z refer to a Cartesian co-ordinate system with axes arranged mathematically like at Gauss-Krueger or UTM co-ordinates. Non-cartesian co-ordinates like the so-called Geographical co-ordinates (longitude, latitude) cannot be processed correctly and must therefore be transformed in advance (e.g. with VECTOR DATA > PROJECTIONS*)!*

Besides the co-ordinates, code commands and end-of-line information will be stored in the vector file. Meaning of the codes:

1 – 3000	single point, general
3501 – 3600	like before, with vector symbol
4001 – 5000	for DTM, with:
4006	significant points, filter resistant
4007	delete start points for free-cut areas (*)
5001 – 8000	points on lines, general
9001 – 9999	for DTM, with:
9008	border polygon for free-cut areas (*)
9009	“smooth” break line, may be filtered
9010	“hard” break line, filter resistant

(*) the z value is without meaning.

Example:

```
5001   -999999.000  -999999.000     1.000      (code 5001)
1000      1000.000     1040.000    20.000
1001      1267.800      807.450    17.000
1002      1600.311     1197.020    21.500
 -99       -99.000      -99.000   -99.000      (end of line)
```

Notes regarding the individual entries:

Point numbers:	Positive integer numbers, maximum 10 digits.
X-, Y-, Z- values:	Real numbers, maximum 12 digits, 3 decimal-digits.
Codes:	Positive integer numbers, maximum 6 digits.

Note regarding the parameter code: Codes between 1 and 5000 stand for single points, code between 5001 and 9999 for lines. It is possible to access particular data within a certain file using codes if, for example, lines have been assigned individual codes following criteria like "field border", "street" etc.

The file is being read line by line. If there are four or more numerical entries in one line, the (first) four are interpreted as No., x, y, z. In case there are only three numerical entries, they are interpreted as x, y, z. The whole line is left out in case there are less than three numerical entries. If the file consists of only x- and y-values, it has to be imported to begin with (option FILE > IMPORT > ASCII ANY SEQUENCE).

Attribute data (.DBF)

Information which refers only to a few locations (e.g. owner of each plot or horizontal expansion of single soil samples) may be managed as attribute data. This is done in DBF files (format dbase IV) which can either be processed in data base programmes. The first field must contain the x-value and the second one the y-value of a referential point, for instance centre co-ordinates of each plot or location co-ordinates of soil samples.

Note concerning the termini: The field corresponds to the column, the data set to a line of a table.

Each field has a well-defined data type. There are different data types:

- Numeric (for numbers) with the sub-types integer or real
- Logical (true or false)
- Text (alphanumerical)

Attribute data can also be used within the raster image display (see DISPLAY RASTER IMAGE > OVERLAY > PHOTOS / TEXTS): In this way you can overlay images (BMP, JPG, TIF) or texts (TXT) onto a geocoded image. The names of the files have to be defined in the DBF file (first field x-value, second field y-value, third field file name). The x-y co-ordinates determine the reference point in the terrain.

Example:

```
1000.000     1040.000     test1.bmp
1267.800      807.450     test2.jpg
1600.311     1197.020     test3.tif
1104.200      973.100     test4.txt
```

Remark: For the use of other file formats (e.g. PDF, AVI) a suitable program must exist on the computer (media player, PDF reader).

Palettes (.PAL)

Palettes can be stored within the central directory `C:\USERS\PUBLIC\LISA\PAL`.

Four entries each row: Colour value, intensities red, green and blue, all entries between 0 and 255. Example:

```
  0   0   0   0
  1   2  51   1
  2   5  54   1
  3   7  56   2
  4  10  58   2
...
255 255 255 255
```

Text reference (.TXT)

Special text file which can be used for example to create a legend. The pixel values are connected with textual information. Example:

The image `LAND.IMA` contains information on the land use in four classes. Then the file `LAND.TXT` can be created with the following structure:

```
2      meadow
12     field
7      forest
8      settlement
```

(each row: Position 1 … 4 colour value, then max. 20 characters text)

Some LISA options create a text reference automatically.

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