Digital Photogrammetric System

PHOTOMOD

Version 7.5

USER MANUAL

LIDAR Data processing

RACURS

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1. Purpose of the document

This document offers information on the processing using *PHOTOMOD* software both third-party lidar data and point clouds created by tools of *PHOTOMOD* software and stored in LAS format.

The *PHOTOMOD* software supports *ASPRS* (*American Society for Photogrammetry and Remote Sensing*) data format.

2. About

Lidar (also written LIDAR or LiDAR) is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light. Aerial LIDAR systems are represented by laser scanner for remote sensing of the earth's surface. *LIDAR data* – it is data obtained by lidar systems, which are installed on aircraft.

LIDAR data (and also some *point clouds*, which can be obtained from another sources) are delivered in LAS format files. LAS format files include the XYZ coordinates of the laser reflection points and their attributes (see the LAS specification published by *ASPRS* and the "LIDAR data loading and displaying" chapter of the current manual and Appendix A).

Points of the laser reflection from the earth's surface, which coordinates and attributes are contained in the LAS format files, is called the *LIDAR points* in this documentation.

The *PHOTOMOD* system also provides possibility to create a file of *point cloud* in the LAS format similar to LIDAR data (exceptions are described below). The point cloud creation in *PHOTOMOD* software is described in "Dense DEM generation using SGM method" chapter of the "DTM Generation" User Manual.

In most cases, the system supports the processing of LAS files regardless of the way the data was received (exceptions are described in an appropriate sections).

To work with lidar data and point clouds, use **Terrain › LAS** menu.

Table 1. Brief description of the "LAS" menu

Menu items	Function
Loas LAS...	opens **Load LAS** window allowing to load LIDAR data
Cut LAS by polygons	allows to edit the area of point cloud coverage
Convert LAS-files to LAZ...	allows to create an archive file with the `*.laz` extension
Convert LAZ-files to LAS...	allows to extract an archive with the `*.laz` extension
Convert LAS to DEM	allows to convert LAS file to DEM
Convert LAS to TrueOrtho	allows to convert LAS file to TrueOrtho

Menu items	Function
LAS Interpolation	allows to change the detalization and the tile size of the LAS points cloud
Transform LAS coordinates	allows to change coordinate system of LAS
LAS filtering	allows to filter LIDAR data by numbers of reflected pulses in each point, by point classes and also by points elevations (especially using external DEM, to remove accident surges)
LAS smooth filter	allows to filter the points cloud, to remove such errors as a noise
LAS bilateral filter	allows to filter the points cloud, to remove such errors as a noise, taking into account points color (if such data are available in the LAS file)
LAS statistical outlier removal filter	allows to filter rough errors, i.e. single points beyond the main cloud at some distance from it, that are very likely erroneous data
LAS fusion filter	allows for point cloud filtering to remove noise taking into account averaged normals from processed points to projection centers of images used in their calculation (if such data are available in the LAS file)
Colorization by project images	provides for colorizing a point cloud using project images
Classification by NDVI	allows for point classification according to NDVI values, in case if the input point cloud initially contains an IR channel (or was created using *PHOTOMOD* software tools from project images containing an IR channel)

3. The “Load LAS” window

Load LAS window is used to load and transform the LIDAR data.

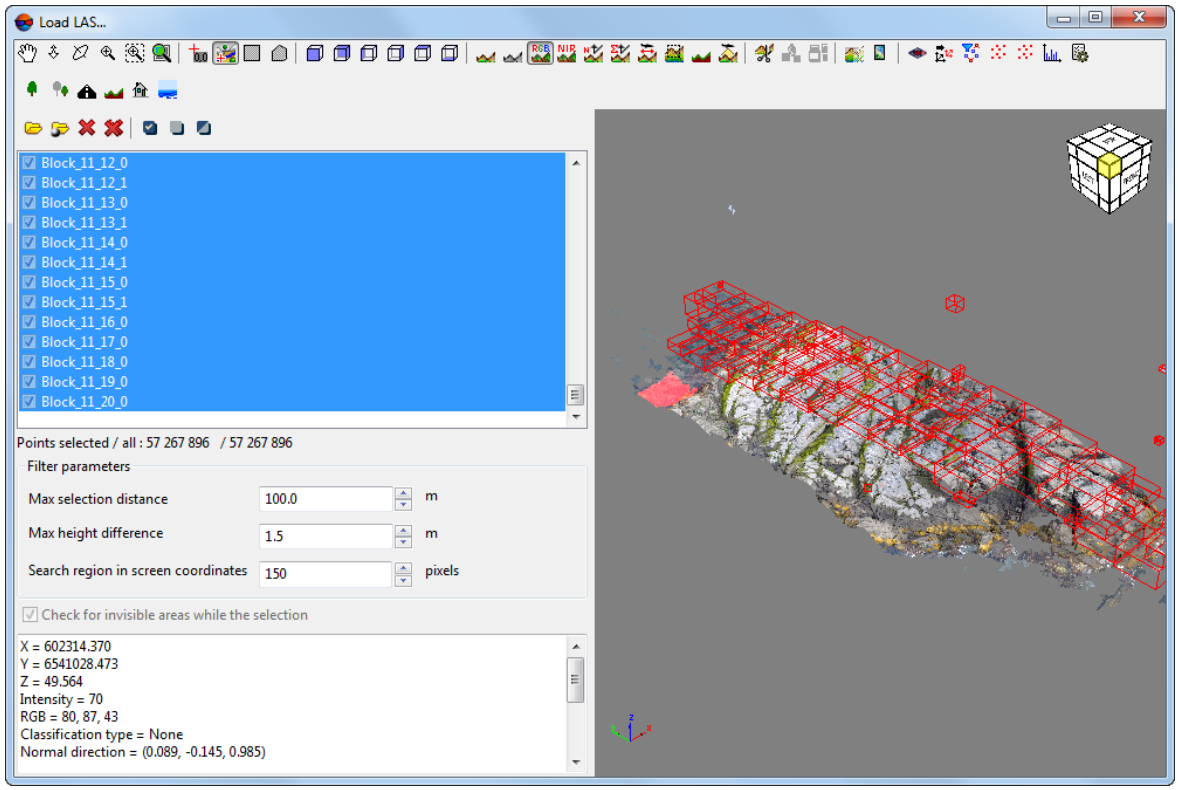

Fig. 1. The “Load LAS” window

Load LAS window contains the following GUI elements:

- toolbar for viewing, editing, analysis and transforming LIDAR data;
- toolbar allowing to classify LIDAR points manually;
- toolbar for loading LIDAR data;
- the workspace with the list of all opened files, in the left part of the window;
  - the drop-down menu, allowing to view the information about loaded LAS-files and perform the **16 bit – 8 bit RGB conversion**.
- a workspace intended for displaying the total number of points in opened files, in the left part of the window;
- the **Filter parameters** section, allowing to specify the algorithm for selecting groups of points, in the left part of the window;
- the area, intended for displaying information about the selected LIDAR point, in the left part of the window;

- working area for LIDAR points viewing, in the right part of the window. This area contains in lower left corner the direction axes of the coordinate system of loaded point cloud.

Table 2. Toolbar allowing to view and edit LIDAR data

Buttons	Functions
	allows to move working area for *LIDAR points* viewing in any direction
	allows to move working area for *LIDAR points* viewing perpendicular to the screen plane
	allows to enable rotation mode and rotate *LIDAR points*
	allows to zoom in/zoom out working area
	allows to zoom in of working area selected by rectangle
	allows to display data in full scale and center it in the window
	allows to display information about the selected LIDAR point
	allows to enable the mode for selecting lidar points located adjacent to each other and presumably having the same origin
	allows to select a group of lidar points inside a rectangle
	allows to select a group of lidar points inside arbitrary polygon
	allows to rotate *LIDAR points*
	allows to display LIDAR points in coloring mode to accordance with its Z-coordinate values
	allows to display *LIDAR points* in coloring mode to accordance with intensity (the return strength of a laser beam per one point), if source LAS file contains such data
	allows to display *LIDAR points* in RGB mode (if source LAS file contains such data)
	allows to display *LIDAR points* in near-infrared mode (if source LAS file contains such data)
	allows to display *LIDAR points* in coloring mode to accordance with serial number of reflected pulse per one point (if source LAS file contains such data)
	allows to display *LIDAR points* in coloring mode to accordance with number of reflected pulses per one point (if source LAS file contains such data)
	allows to display *LIDAR points* in coloring mode to accordance with scan direction (if source LAS file contains such data)

Buttons	Functions
	allows to display *LIDAR points* in coloring mode to accordance with edges (if source LAS file contains such data)
	allows to display *LIDAR points* in coloring mode to accordance with scan angle (if source LAS file contains such data)
	allows to display *LIDAR points* in coloring mode to accordance with objects classification (if source LAS file contains such data)
	allows to split the loaded LIDAR data
	allows to eneble/disable displaying of splitting grid
	allows to save parts of LIDAR data corresponding to created splitting into separate LAS files
	allows to convert to DEM all the point clouds, which are displayed in working area in the right part of the window
	allows to convert to TrueOrtho all the point clouds, which are displayed in working area in the right part of the window
	allows to change the detalization and the tile size of the LAS points cloud
	allows to change coordinate system of LAS
	allows to filter LIDAR data by numbers of reflected pulses in each point, by point classes and also by points elevations (especially using external DEM, to remove accident surges)
	allows to filter the points cloud, to remove such errors as a noise
	allows for point cloud filtering to remove noise taking into account averaged normals from processed points to projection centers of images used in their calculation (if such data are available in the LAS file)
	allows to configure loaded LAS settings in the workspace to display lidar points

Table 3. Toolbar allowing to classify LIDAR data

Buttons	Functions
	allows assign the **high vegetation** standard class to manually selected () lidar points (5)
	allows assign the **low vegetation** standard class to manually selected lidar points (3)
	allows assign the **road surface** standard class to manually selected lidar points (11)
	allows assign the **ground** standard class to manually selected lidar points (2)

Buttons	Functions
	allows assign the **building** standard class to manually selected lidar points (6)
	allows assign the **water** standard class to manually selected lidar points (9)
	allows assign the **transport** class to manually selected lidar points. This class is used in *PHOTOMOD* and is not a part of the *ASPRS*-developed standard classification (this software uses one of the "reserved" classes, considering it as transport, inside the *PHOTOMOD* system).
	allows assign the **Created, never classified** standard class to manually selected lidar points (0)

Table 4. Toolbar allowing to load LIDAR data

Buttons	Functions
	allows to open the LAS format files with LIDAR data located in a folder of *Windows* file system
	allows to open the LAS format files with LIDAR data located in active profile resources
	allows to close selected LAS format files with LIDAR data
	allows to close all opened LAS format files with LIDAR data
	allows to save the selected point cloud areas as a separate files in the active profile resources
	allows to select all items in the list of all opened files
	allows to deselect all items in the list
	allows to invert items selection

3.1. LIDAR data loading

The system allows to import lidar data as a vector layer (in the form of points, see the "Import from LAS" chapter of the "Vectorization" User Manual).

In order to load and display LIDAR data perform the following actions:

1. Choose **Terrain › LAS › Load LAS...**. The **Load LAS** window opens.
2. Perform one of the following actions:
   - [optional] Click the  button to load files located in a folder of *Windows* file system;
   - [optional] Click the  button to load files located in active profile resources.

The list of loaded files is displayed in the workspace, in the left part of the window. To show (or hide) data from loaded files in the workspace located in the right part of the window, set (or clear) the appropriate checkboxes.

Use the **left mouse button** to select loaded files (point cloud tiles) in the work area with the list of loaded files (and, simultaneously, in the work area intended for displaying lidar points).

The selection of files is available both in the list in the left part of the window, and in the area intended for displaying lidar points in the right part of the window.

To view the information on downloaded LAS-files, select the appropriate files in the workspace with a list of downloaded files by clicking the left mouse button and open the drop-down menu by clicking the right mouse button. Choose **LAS files info** to open the window containing information about the points number in every opened LAS-file.

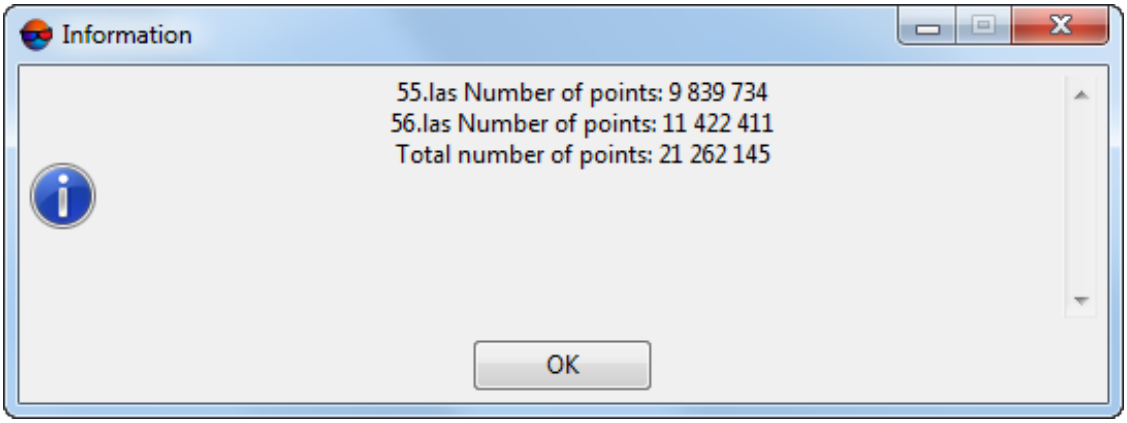

Fig. 2. The “Information” window

The number of points in the loaded LAS files is also displayed in the workspace in the left part of the window directly under the list of loaded files. Two parameters are displayed in this workspace:

- **Points (all)** – is the sum of points in all the loaded LAS files;
- **Points (selected)** – is the total number of points contained in the clouds intended for visual display in the workspace located in the right part of the window.

To display any given point cloud in the workspace in the right part of the window, set the appropriate checkbox in the list of loaded LAS files.

To convert 16-bit color LAS-files, select the appropriate files in the workspace with a list of downloaded files and open the drop-down menu by clicking the right mouse button and enable the mode that allows to perform **16 bit – 8 bit RGB convesion**.

For invert conversion, disable the mode that allows to perform **16 bit – 8 bit RGB convesion**, by re-selecting the appropriate item in the drop-down menu.

System provides the following features to control the display of loaded *LIDAR points*:

- use the mouse wheel for scaling points or use , , and buttons;
- click the button and move cursor in the working area with the pressed left mouse button to rotate or use , , , , and buttons;

To display information about a point of interest set the point selection mode () and select a point in working area for LIDAR points viewing (by mouse left click). The following data appears in lower left corner of the **Load LAS** window (if LAS file contains such data):

Together with a lidar point in the view area on the right, the appropriate LAS-file to which this point belongs is selected.

- Coordinates, **X**, **Y**, **Z**;

  Click the button to enable the height coloring mode.

- The **Intensity** value – the integer representation of the pulse return magnitude;

  Click the button to enable the intensity coloring mode.

- **RGB** or **RGBN** values (if LAS file contains NIR channel);

  Click the button to enable the RGB coloring mode.

  Click the button to display LIDAR points in near-infrared mode (if LAS file contains NIR channel).

  The IR band is supported e.g. for some data record formats in v1.4 LAS files (Point Data Record Format 8). Format and version of initial LAS files depend on data provider. For more info see *ASPRS* v1.4 LAS specifications.

  PHOTOMOD also provides for creating a point cloud that contains detailed data (if initial images have an IR band, see “Dense DEM generation using SGM method” in the “DTM Generation” User Manual).

- [optional] **NVDI** value (if LAS file contains NIR channel);

  NDVI is the normalized difference *vegetation index*. Vegetation index is a numerical indicator of the quality and quantity of vegetation in the studied area.

NDVI is one of the most widely used vegetation indices. It is the ratio between the difference in the intensities of reflected light in the red (Red) and near infrared (NIR) bands and their sum:

```
NDVI = (NIR - RED) / (NIR + RED)
```

PHOTOMOD provides for classifying lidar points according to NDVI (see the "Classification by NDVI" chapter).

It should be taken into account that the intensity of the reflected color in the infrared band and the **point class** (see below) are the properties of a lidar point, that (optionally, if such data are available) can be recorded in a LAS file, unlike the NDVI index, which is calculated by the system when accessing a particular point selected by the user.

- **Classification type** – see the "LAS Specification 1.4" published by *ASPRS* and the "Classification by NDVI" chapter of the current manual (see also Appendix A);

  Click the button to enable the coloring mode to accordance with objects classification.

  The value of the **point class** parameter initially depends on the data provider (the point may be not classified), and later on - on the subsequent processing that the point cloud is subjected to (for example, lidar point classification according to the NDVI index, using the *PHOTOMOD* software, performed with user settings).

  Thereof, in the latter case (depending on the settings specified by the user during the latest classification) the mutual ratio of the current **point class** and the calculated NDVI index may not comply with common standards.

  Classes assigned to DEM cells are automatically considered during DEM conversion in a LAS point cloud (see "DEM classification" and "Convert DEM to point cloud (LAS)" in the "DTM Generation" User Manual).

- [optional] **Normal direction** from point to projection centers of images, used in calculation of the current point (only if LAS file was created in *PHOTOMOD* software, see the "Dense DEM generation using SGM method" chapter of the "DTM Generation" User Manual and the "LAS fusion" chapter of current manual);

- **Classification flags** – see the "LAS Specification 1.4" published by *ASPRS*;

- **Return number** – see the "LAS Specification 1.4" published by *ASPRS*;

  Click the button to enable the coloring mode to accordance with serial number of reflected pulse per one point.

  Service data used by the system are recorded as the **return number** parameter values in the point cloud created by *PHOTOMOD*.

- **Number of returns** – see the "LAS Specification 1.4" published by *ASPRS*;

Click the button to enable the coloring mode to accordance with number of reflected pulses per one point.

In case of the cloud of points, created during the DEM creation using the SGM method, the number of reflected pulses in the given point ( ) is the number of stereopairs on the basis of which a particular point was calculated: 1, 2, 3, 4, 5, 6, 7, or 8. Limitation of the “number of reflected pulses” by 1 to 8 results from the limitations of the LAS format itself, accordingly, in the latter case, the number of stereopairs can be both “8” and “8 and more”.

Table 5. Points coloring modes

Point color	Number of reflected pulses per point	Serial number of reflected pulse
	no data available	no data available
	1	1
	2	2
	3	3
	4	4
	5	5
	6	6
	7	7
	8 or more	8

- **Scanner channel** – see the “LAS Specification 1.4” published by *ASPRS*;
- **Scan Direction Flag** – see the “LAS Specification 1.4” published by *ASPRS*;

Click the button to enable the coloring mode to accordance with scan direction.

- **Edge of Flight Line** – see the “LAS Specification 1.4” published by *ASPRS*;
- **Scan angle** – see the “LAS Specification 1.4” published by *ASPRS*.

Click the button to enable the coloring mode to accordance with scan angle.

3.2. LIDAR data rendering settings

To configure the display settings for downloaded point clouds in the workspace (3D-scene) of the **Load LAS** window, click the button in the toolbar of this window. The **Settings** window opens:

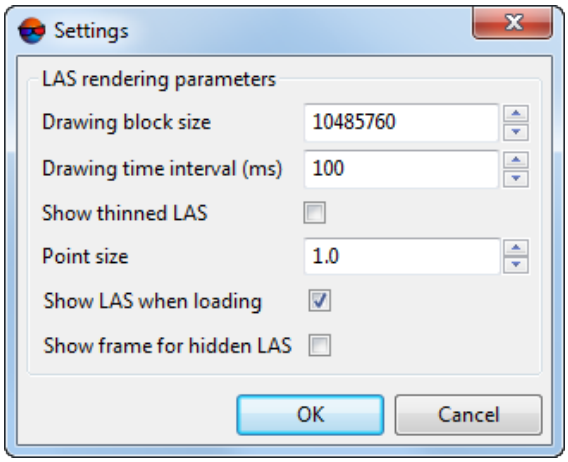

Fig. 3. The “Settings” window

Set the following options in the **Settings** window:

- **Drawing block size** (points number);
- **Drawing time interval** (ms);
- **Point size**;
- To **show thinned LAS**, set the appropriate checkbox;
- To **show LAS when loading**, set the appropriate checkbox;
- To **show frame for hidden LAS**, set the appropriate checkbox.

Click OK. Rebuilding of the loaded LAS starts in the workspace of the **Load LAS** window.

3.3. Selecting point groups

The system provides the following modes of group lidar point selection for their further deletion, manual classification or saving as a separate files in the active profile resources.

Table 6. Main “Load LAS”, toolbar buttons intended for group selection of lidar points

Buttons	Functions
	allows to enable the mode for selecting lidar points with similar color characteristics located adjacent to each other and presumably having the same origin
	allows to select a group of lidar points inside a rectangle
	allows to select a group of lidar points inside arbitrary polygon

The system provides an algorithm for selecting groups of points located adjacent to each other, and, presumably, describing some separate, distinct object. Both point attributes and their mutual arrangement are to be analyzed there.

To do this, perform the following:

1. [optional] configure the algorithm for point group selection in the appropriate section of **Load LAS** window;

2. Click the button in the **Load LAS** window toolbar to enable the mode for selecting lidar poing groups presumably having the same origin;

3. To select a point group, move mouse cursor over the appropriate area of the point cloud in the work area intended for lidar point display in the right part of the **Load LAS** window and click it by the **left mouse button**. The area of the point cloud (selected according to the search algorithm and the specified settings) is highlighted using a color fill);

4. [optional] To add another one (or more) point cloud areas to the selected one, move the marker and click desired point cloud areas by the **left mouse button** holding down **Ctrl**;

5. [optional] To cancel selection, press **Esc**. If several areas of the point cloud were selected at once (see the previous paragraph), then the selection would be cancelled from the last selected area in turn. In this case, to cancel the selection on the whole, press **Esc** the appropriate number of times (or start the process of selecting areas of the point cloud again without holding **Ctrl**;

6. Make sure that the desired areas of the point cloud are highlighted with color fill.

The system allows user also to select lidar points inside a rectangular polygon. For this, perform the following:

1. [optional] configure the algorithm for point group selection in the appropriate section of **Load LAS** window – in order not to add points which are “invisible” to a user under condition of current arrangement of the set of lidar data, set the **check hidden zones in selection process** checkbox;

2. Click in the **Load LAS** toolbar;

3. To select lidar points, press and hold the **left mouse button** and “stretch” the rectangle in the work area with lidar points. The area of the point cloud (selected according to the specified settings) is highlighted using a color fill);

4. [optional] To add another one (or more) point cloud areas to the selected one, repeat the steps from the above paragraph holding **Ctrl**;

5. [optional] To cancel selection, press **Esc**. If several areas of the point cloud were selected at once (see the previous paragraph), then the selection would be cancelled from the last selected area in turn. In this case, to cancel the selection on the whole, press **Esc** the appropriate number of times (or start the process of selecting areas of the point cloud again without holding **Ctrl**;

6. Make sure that the desired areas of the point cloud are highlighted with color fill.

To select lidar points within an arbitrary-shaped polygon, perform the following:

1. [optional] configure the algorithm for point group selection in the appropriate section of **Load LAS** window – in order not to add points which are “invisible” to a user under condition of current arrangement of the set of lidar data, set the **check hidden zones in selection process** checkbox;

2. Click  in the **Load LAS** toolbar;

3. Create a rectangular polygon moving the cursor step-by-step in the work area with lidar points and pressing the **left mouse button**. The created polygon is visually displayed with dashed gray lines. To complete the rectangle creation, press **Enter** (or mouse near the first rectangle’s vertex and click the **left mouse button**). The area of the point cloud (selected according to the specified settings) is highlighted using a color fill);

4. [optional] To add another one (or more) point cloud areas to the selected one, repeat the steps from the above paragraph holding **Ctrl**;

5. [optional] To cancel selection, press **Esc**. If several areas of the point cloud were selected at once (see the previous paragraph), then the selection would be cancelled from the last selected area in turn. In this case, to cancel the selection on the whole, press **Esc** the appropriate number of times (or start the process of selecting areas of the point cloud again without holding **Ctrl**;

6. Make sure that the desired areas of the point cloud are highlighted with color fill.

3.3.1. Points selection settings

The **Filter parameters** section, allowing to specify the algorithm for selecting groups of points, is situated in the left part of the **Load LAS** window;

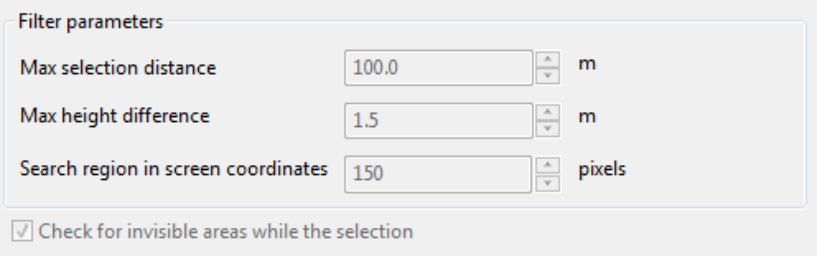

Fig. 4. The “Filter parameters” section

The system provides to specify the algorithm for selecting groups of points located adjacent to each other ( ):

- **Max selection distance**, in project units;
- **Max height difference**, in project units;
- **Search region in screen coordinates**, in pixels;

Set the **check hidden zones in selection process** checkbox when selecting lidar points within polygons (,), in order not to add points which are, “invisible” to the user under condition of current arrangement of the set of lidar data (in the **Load LAS** work area supposed for lidar point viewing).

The button of the main **Load LAS** toolbar enables the mode of rotating the lidar data set in an arbitrary way.

4. Operations with LIDAR data

4.1. Point cloud boundaries

4.1.1. Splitting into sheets

The system provides the splitting into sheets of loaded LIDAR data to save data in the separate LAS format files or to select one or another parts of source LAS format file for DEM building.

To split the LIDAR data into sheets do the following actions:

1. Click the or button to load files. Choose one or more files in LAS format and click OK.
2. Choose one or more files in LAS format and click the button to specify splitting settings. **Splitting settings** window opens.

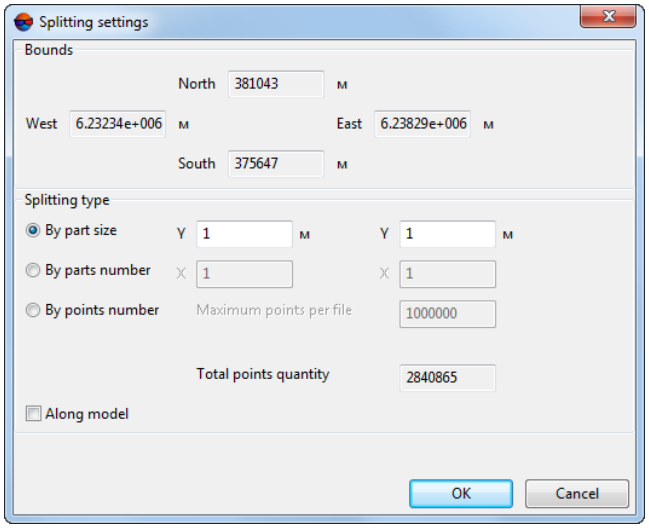

Fig. 5. “Splitting settings” window

The window displays the values of the lidar data area boundaries, in the **Bounds** section.

3. In the **Splitting type** panel select the splitting type by check box and specify the parameters:
   - **By part size** – splitting sheet’s size along X and Y axes in meters defines;
   - **By parts number** – number of splitting sheets along X and Y axes defines;
   - **By points number** – max number of *LIDAR points* per single splitting sheet in the **Max points per single file** entry field.
4. [optional] To split data along extended fringe of model, set the **Along model**.
5. Click OK. **Splitting settings** window closes. Sheet frames for selected file are displayed in **Load LAS** window.

Use the button for turning on/off the sheet frames displaying mode.

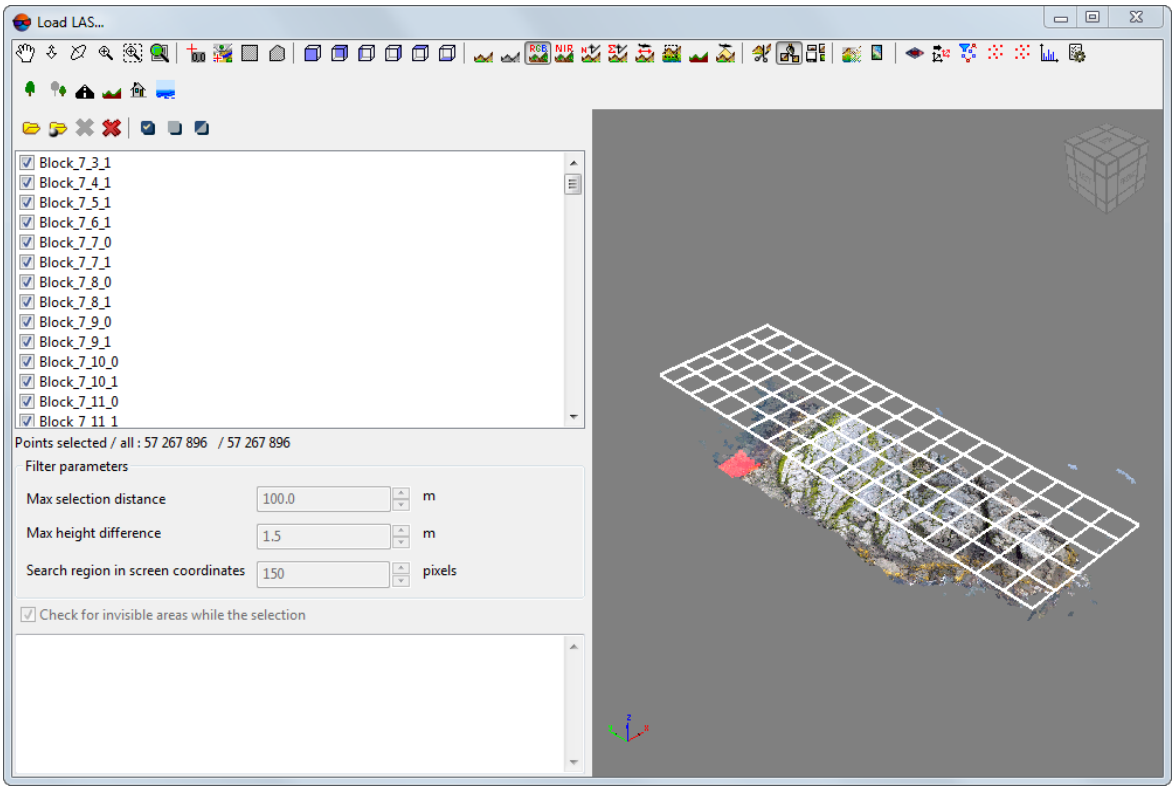

Fig. 6. Splitting sheets displaying

6. Click the button to save the LIDAR data from splitting sheets in the separate LAS format files. **Save** window opens.

7. Specify the folder of active profile and *left part* of the name for creating the LAS format files.

8. Click OK. The file is created for each sheet. The name of this file is created from the specified initial part, the filename of splitting of LIDAR data and the serial number in accordance with the number of the splitting sheets.

4.1.2. Point cloud cutting by polygons

The system allows to edit the area of point cloud coverage.

In order to correct point cloud area, perform the following actions:

1. Create vector layer and polygons in it, or open a layer with bordering polygons (see the 'Vectorization' User Manual).

   If polygons used as boundaries have no attributes, create *text* attributes for them before point cloud cutting and save the vector layer (see the 'Vectorization' User Manual).

   The use of numeric attributes is not allowed for this operation.

Names of output LAS-files (and also names of output folders containing these LAS-files) are to be set automatically from the object attribute values used as boundaries for cutting.

2. Select **Terrain › LAS › Cut LAS by polygons**. The **Cut LAS by polygons** window opens.

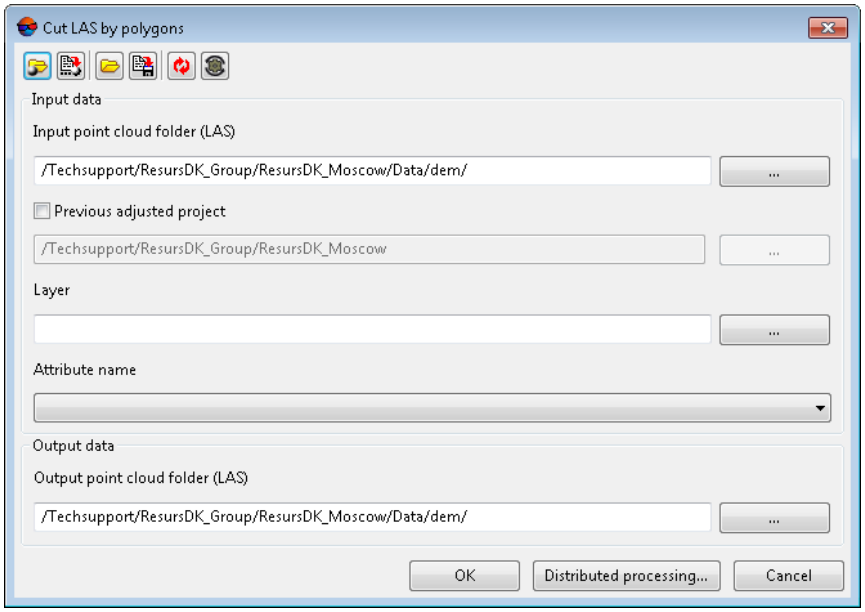

Fig. 7. Parameters of cutting by polygons

A toolbar in the upper part of the window is intended to save/load parameter's settings and contains the following buttons:

- – allows to load parameter's settings saved previously to active profile resources;
- – allows to save all parameter's settings to `*.x-ini` file located in active profile resources;
- – allows to load parameter's settings from *`*.x-ini`* file located in a folder of *Windows* file system;
- – allows to save parameter's settings to `*.x-ini` file located in a folder of *Windows* file system;
- – allows to restore the last-session's settings;
- – allows to restore default parameter's settings.

3. In the **Input data** section click the ... button in the **Input point cloud folder (LAS)** field to select input folder with LAS-files in active profile resources.

4. [optional] To define a **Previous adjusted project** in active profile resources, click the ... button in the **Previous adjusted project** field.

   

   This operation may be required if the project (or its copy) was readjusted after the LAS-file creation.

5. To define the vector **Layer** with polygons used as boundaries in active profile resources, click the ... button in the **Layer** field.

6. Input the **Attribute name** of polygons used as boundaries in **Attribute name** field;

7. In the **Output data** section click the ... button in the **Output point cloud folder (LAS)** field to specify output folder, containing folders with output LAS-files in active profile resources.

8. Click OK.

   To edit DEM in distributed processing mode, perform the following actions:

   1. Change settings and run the distributed processing server/client (see the “Distributed processing” chapter in the “General information” User Manual).

   2. Click the **Distributed processing** button. Distributed processing tasks are created. Number of created tasks matches with number of LAS-files.

4.2. Converting points cloud

4.2.1. DEM creation

The system allows to convert LIDAR data to DEM for the further usage in the *PHOTOMOD* system.

For DEM building perform the following actions:

1. Choose **Terrain › LAS › Convert LAS to DEM**. The **Convert LAS to DEM** window opens:

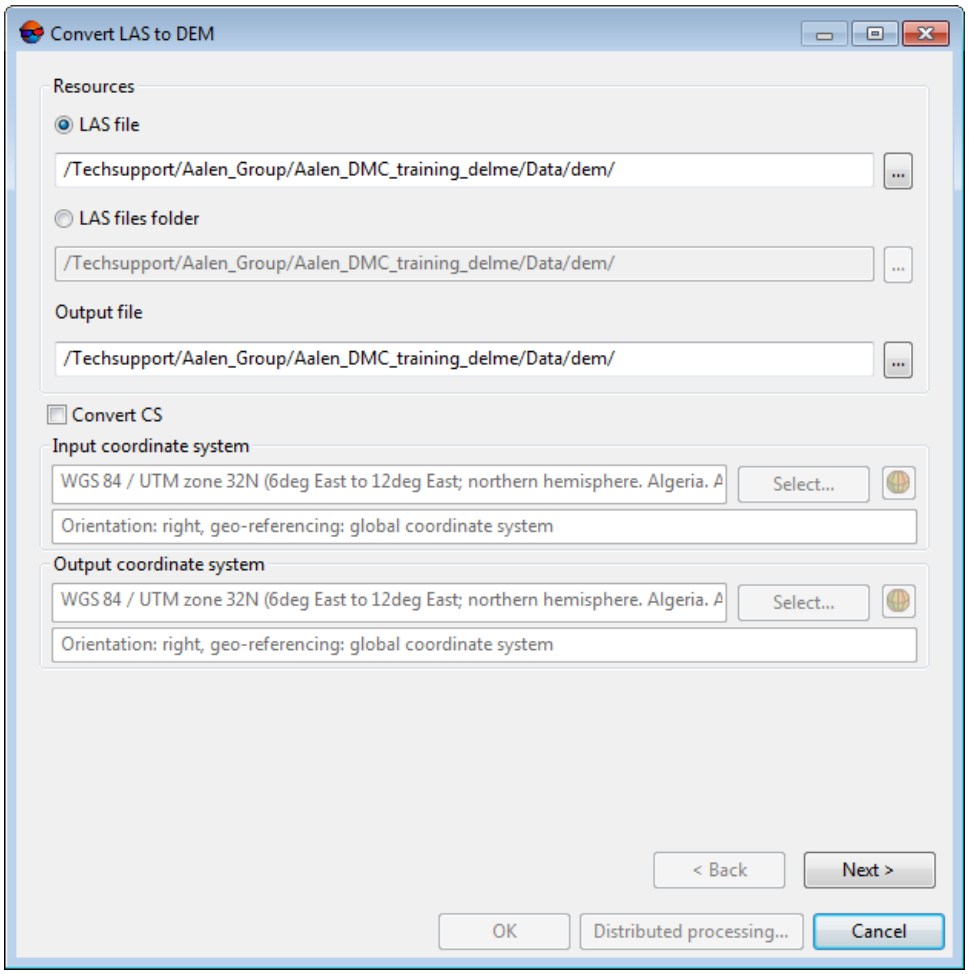

Fig. 8. The “Convert LAS to DEM” window

2. Select the input **Resources**:
   - [optional] **LAS file** – to process a point cloud saved as a single file;
   - [optional] **LAS files folder** – to process a fragmented point cloud.
3. Specify the **output file** location in active profile resources;
4. [optional] to change points cloud coordinate system, perform the following actions:
   - In the **Input coordinates system** section select actual Coordinate system of point cloud. Perform the following actions to do this:
     1. Click the **Select...** button to specify initial coordinate system.

        Coordinate system is specified using one of the following ways:

- **From DB** – from international or Russian coordinate system database (see *'Coordinate systems databases'* in the Project creation' User Manual);
- **From file** – allows to select coordinate system from files with `*.x-ref-system`, extension located out of active profile resources;
- **From resource** – from files with `*.x-ref-system` extension located in active profile resources, for example, to select coordinate system from another active profile project.
- **From GeoCalculator** – from the list of *GeoCalculator* program database (see the "Coordinate Systems" chapter in "The GeoCalculator program" User manual).

The *GeoCalculator* program allows to edit coordinate systems, to create new ones, to perform import and export of coordinate systems (see the "The GeoCalculator program" User Manual).

The system also allows to select coordinate system from a list of recently used coordinate systems.

2. [optional] When choosing coordinate system from database the **Coordinate system database** opens, which contains the list of coordinate systems.

To perform fast search for coordinate system, input the whole coordinate system name or its part to the **Find** input filed.

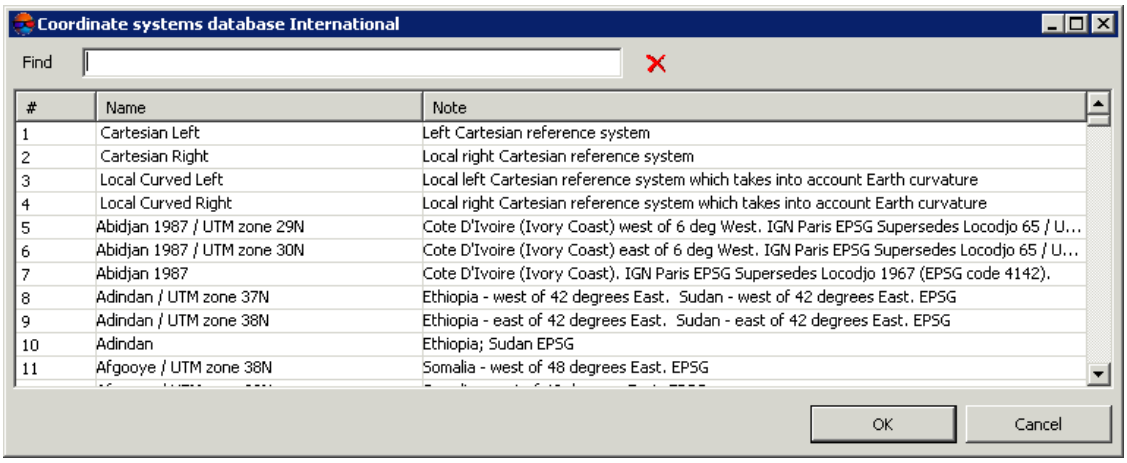

Fig. 9. Window used to select coordinate system from coordinate system database

3. [optional] To choose geoid to be used, click the button. Select proper type of geoid usage:
   - **No geoid**;

- **EGM 96**.

The system allows to use the EGM2008 geoid. See more details in the Installation EGM2008 Geoid User Manual. After installation the geoid is displayed in the list.

- In the **Output coordinate system** define target coordinate system in which it is necessary to convert the point cloud. To do this perform actions from step **4**.

5. Click **Next**. **Estimated DEM size**, **width**, **height**, and **boundaries** will be calculated in the **Convert LAS to DEM** window:

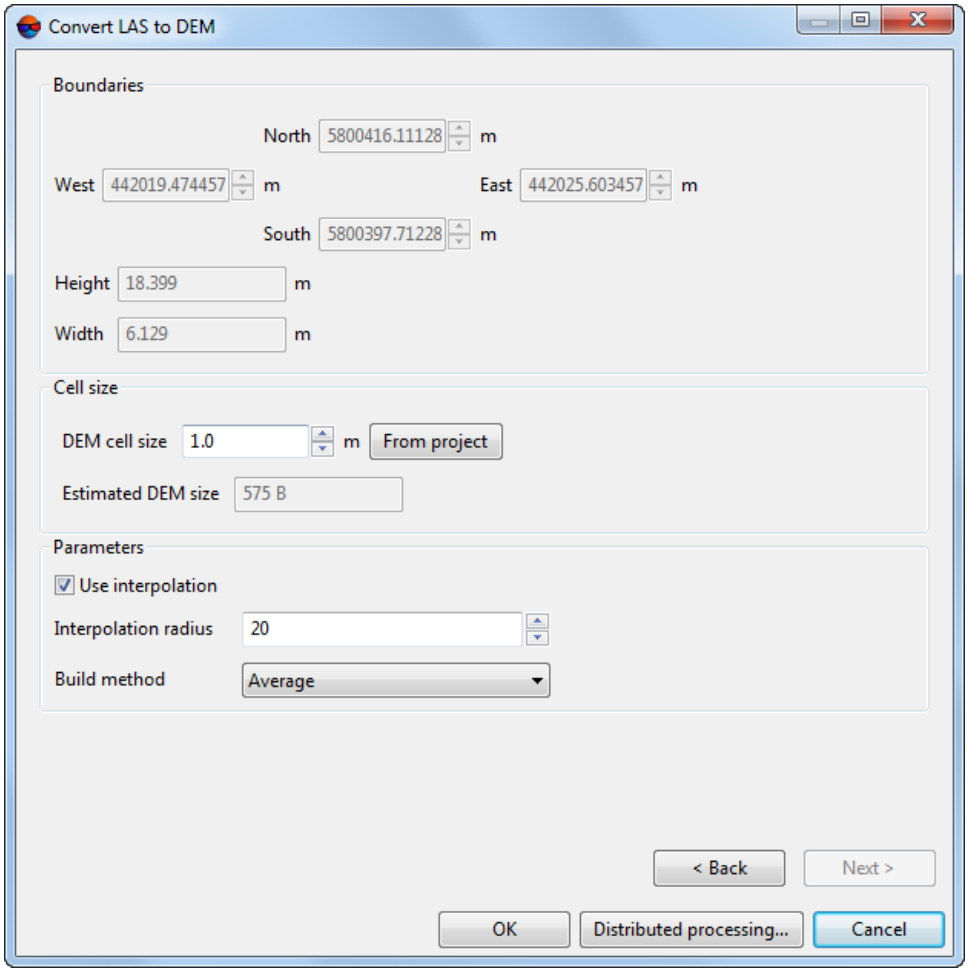

Fig. 10. The “Convert LAS to DEM” window

6. Specify the **DEM cell size** in meters. Automatic recalculation of the **Estimated DEM size** is performed while change the **DEM cell size**;

7. Set the DEM building **parameters**:

- To **use interpolation** set an appropriate checkbox and specify the **interpolation radius**;
- Select the **build method**:
  - **Average**;
  - **Select value from max height point**;
  - **Select max weight point**;
  - **Select point with max quality**.

8. Click OK to start conversion. To use distributed computing for point cloud conversion, do the following:
   1. Change settings and run the distributed processing server/client (see the 'Distributed processing' chapter in the 'General information about system' User Manual).
   2. Click the **Distributed processing** button. Distributed processing tasks are created.
9. The created DEM is opened in 2D-window when the process completes.

To convert all point clouds opened in **Load LAS** window into single DEM – click the  button in main **Load LAS** window toolbar and specify the parameters described above.

Point clouds will be transformed into a single DEM. Only the clouds displayed in the workspace in the right part of the **Load LAS** window will be transformed.

To display any given point cloud in the **Load LAS** workspace, set the appropriate checkbox in the list of loaded LAS files.

Coordinate system change and distributed processing are not available in the case of rapid transform of LAS files started from the toolbar of the **Load LAS** window.

4.2.2. True Ortho creation

The system allows to convert LIDAR data to True Ortho for the further usage in the *PHOTOMOD* system.

For True Ortho building perform the following actions:

1. Choose **Terrain › LAS › Convert LAS to True Ortho**. The **Convert LAS to True Ortho** window opens:

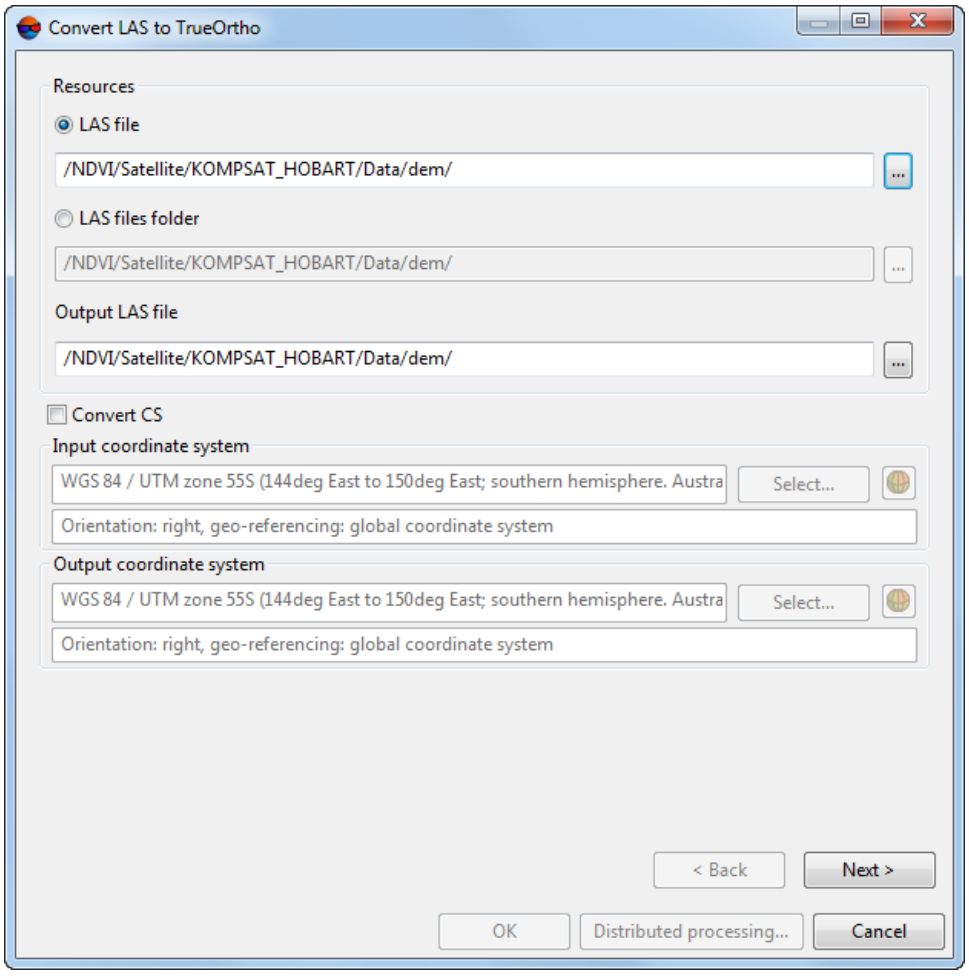

Fig. 11. The “Convert LAS to True Ortho” window

2. Select the input **Resources**:
   - [optional] **LAS file** – to process a point cloud saved as a single file;
   - [optional] **LAS files folder** – to process a fragmented point cloud.
3. Specify the **output resource**;
4. [optional] to change points cloud coordinate system, perform the following actions:
   - In the **Input coordinates system** section select actual Coordinate system of point cloud. Perform the following actions to do this:
     1. Click the **Select...** button to specify initial coordinate system.

        Coordinate system is specified using one of the following ways:

- **From DB** – from international or Russian coordinate system database (see *'Coordinate systems databases'* in the Project creation' User Manual);
- **From file** – allows to select coordinate system from files with `*.x-ref-system`, extension located out of active profile resources;
- **From resource** – from files with `*.x-ref-system` extension located in active profile resources, for example, to select coordinate system from another active profile project.
- **From GeoCalculator** – from the list of *GeoCalculator* program database (see the "Coordinate Systems" chapter in "The GeoCalculator program" User manual).

The *GeoCalculator* program allows to edit coordinate systems, to create new ones, to perform import and export of coordinate systems (see the "The GeoCalculator program" User Manual).

The system also allows to select coordinate system from a list of recently used coordinate systems.

2. [optional] When choosing coordinate system from database the **Coordinate system database** opens, which contains the list of coordinate systems.

To perform fast search for coordinate system, input the whole coordinate system name or its part to the **Find** input filed.

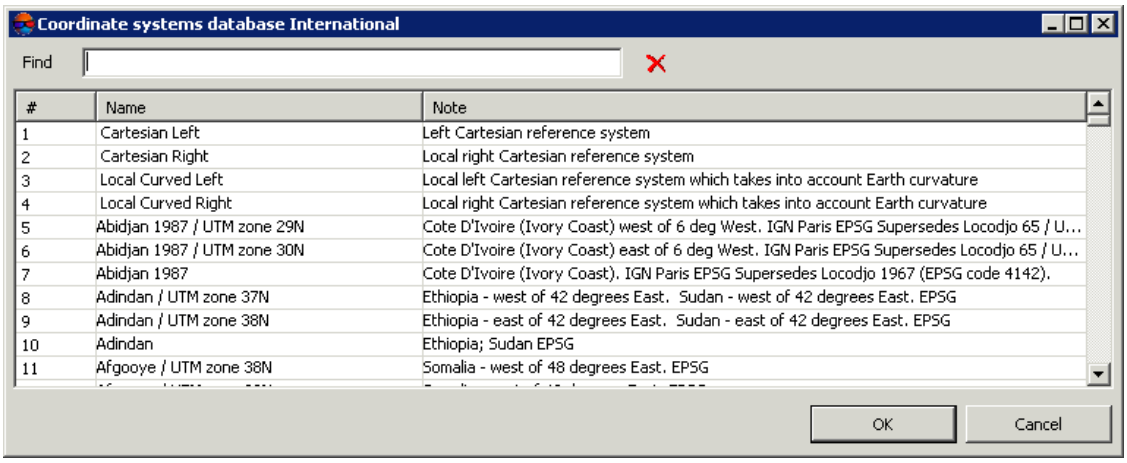

Fig. 12. Window used to select coordinate system from coordinate system database

3. [optional] To choose geoid to be used, click the button. Select proper type of geoid usage:

- **No geoid**;

- **EGM 96**.

The system allows to use the EGM2008 geoid. See more details in the Installation EGM2008 Geoid User Manual. After installation the geoid is displayed in the list.

- In the **Output coordinate system** define target coordinate system in which it is necessary to convert the point cloud. To do this perform actions from step **4**.

5. Click **Next**. **Estimated true ortho size**, **width**, **height**, and **boundaries** will be calculated in the **Convert LAS to true ortho** window:

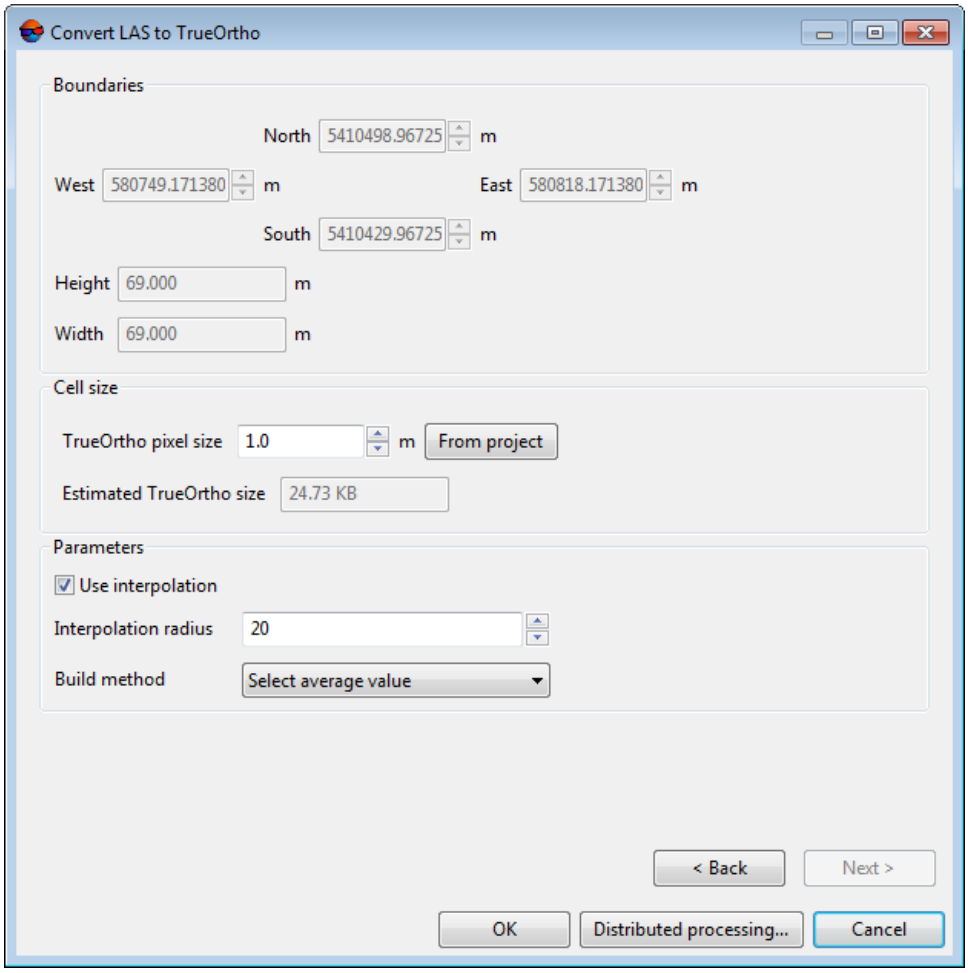

Fig. 13. The “Convert LAS to True Ortho” window

6. Specify the **true ortho pixel size** in meters. Automatic recalculation of the **Estimated true ortho size** is performed while change the **true ortho cell size**;

7. Set the true ortho building **parameters**:

- To **use interpolation** set an appropriate checkbox and specify the **interpolation radius**;
- Select the **build method**:
  - **Average**;
  - **Select value from max height point**;
  - **Select max weight point**;
  - **Select point with max quality**.

8. Click OK to start conversion. To use distributed computing for point cloud conversion, do the following:
   1. Change settings and run the distributed processing server/client (see the 'Distributed processing' chapter in the 'General information about system' User Manual).
   2. Click the **Distributed processing** button. Distributed processing tasks are created.
9. The created true ortho is opened in 2D-window when the process completes.

To convert all point clouds opened in **Load LAS** window into single orthoimage – click the button of main **Load LAS** window toolbar and specify the parameters described above.

Point clouds will be transformed into a single orthophotomap. Only the clouds displayed in the workspace in the right part of the **Load LAS** window will be transformed

To display any given point cloud in the **Load LAS** workspace, set the appropriate checkbox in the list of loaded LAS files.

Coordinate system change and distributed processing are not available in the case of rapid transform of LAS files started from the toolbar of the **Load LAS** window.

4.2.3. Transformation of point cloud coordinate system

The system provides opportunity to transform LAS-files from one coordinate system to another.

In order to transform LAS-files to another coordinate system perform the following actions:

1. Select **Terrain › LAS › Transform LAS coordinates**. The **Transform LAS coordinates** window opens.

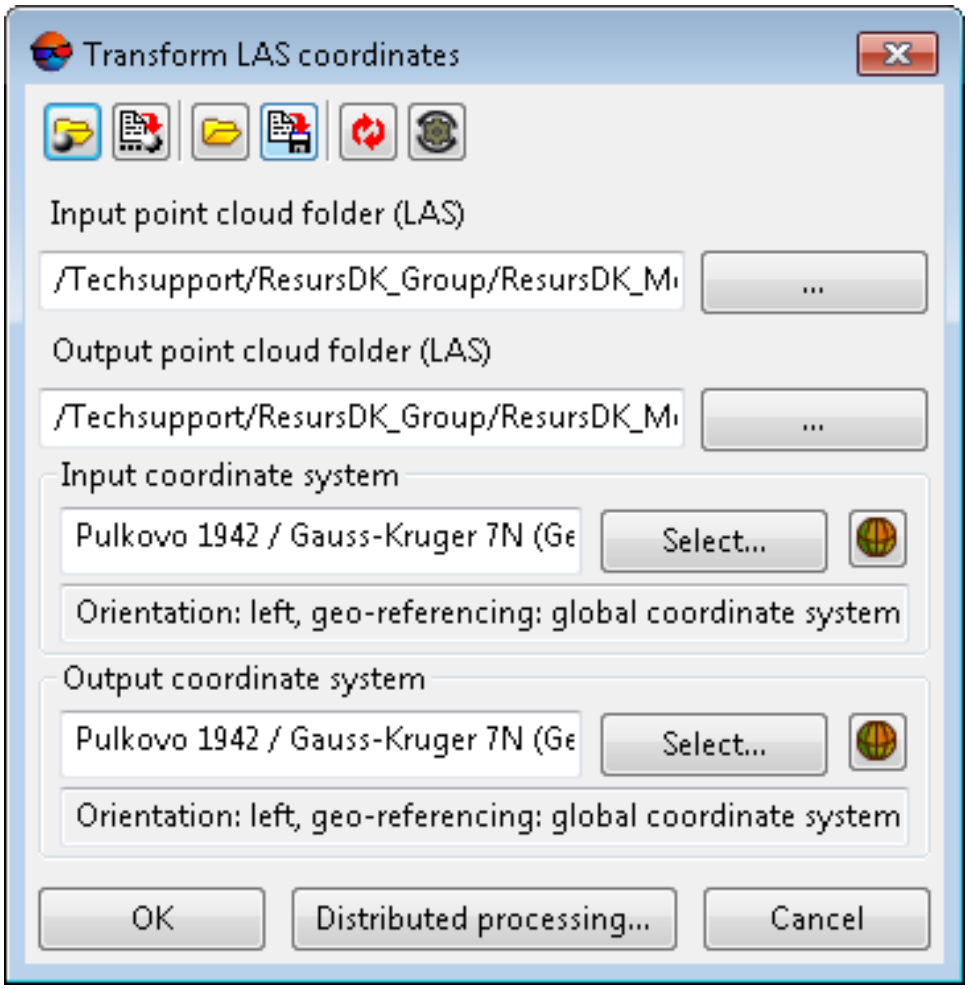

Fig. 14. Transform LAS to another coordinate system

A toolbar in the upper part of the window is intended to save/load parameter's settings and contains the following buttons:

- – allows to load parameter's settings saved previously to active profile resources;
- – allows to save all parameter's settings to `*.x-ini` file located in active profile resources;
- – allows to load parameter's settings from *`*.x-ini`* file located in a folder of *Windows* file system;
- – allows to save parameter's settings to `*.x-ini` file located in a folder of *Windows* file system;
- – allows to restore the last-session's settings;
- – allows to restore default parameter's settings.

2. Click the ... button in the **Input point cloud folder (LAS)** section and specify a source folder with point cloud in active profile resources.

3. Click the ... button in the **Output point cloud folder (LAS)** section and specify target folder for output LAS-files in active profile resources.

4. In the **Input coordinates system** section select actual Coordinate system of point cloud. Perform the following actions to do this:

    1. Click the **Select...** button to specify initial coordinate system.

        Coordinate system is specified using one of the following ways:

        - **From DB** – from international or Russian coordinate system database (see *'Coordinate systems databases'* in the Project creation' User Manual);
        - **From file** – allows to select coordinate system from files with `*.x-ref-system`, extension located out of active profile resources;
        - **From resource** – from files with `*.x-ref-system` extension located in active profile resources, for example, to select coordinate system from another active profile project.
        - **From GeoCalculator** – from the list of *GeoCalculator* program database (see the "Coordinate Systems" chapter in "The GeoCalculator program" User manual).

        

        The *GeoCalculator* program allows to edit coordinate systems, to create new ones, to perform import and export of coordinate systems (see the "The GeoCalculator program" User Manual).

        

        The system also allows to select coordinate system from a list of recently used coordinate systems.

    2. [optional] When choosing coordinate system from database the **Coordinate system database** opens, which contains the list of coordinate systems.

        

        To perform fast search for coordinate system, input the whole coordinate system name or its part to the **Find** input filed.

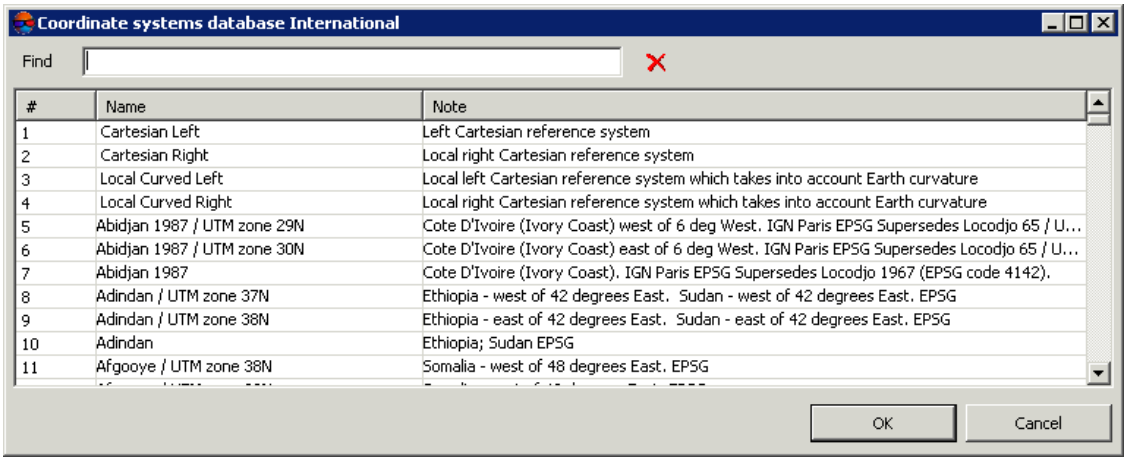

Fig. 15. Window used to select coordinate system from coordinate system database

3. [optional] To choose geoid to be used, click the button. Select proper type of geoid usage:

   - **No geoid**;
   - **EGM 96**.

   The system allows to use the EGM2008 geoid. See more details in the Installation EGM2008 Geoid User Manual. After installation the geoid is displayed in the list.

5. In the **Output coordinate system** define target coordinate system in which it is necessary to convert the point cloud. To do this perform actions from step **4**.

6. Click OK to start converting point cloud coordinate system.

   To use distributed computing for changing of point cloud coordinate system, do the following:

   1. Change settings and run the distributed processing server/client (see the 'Distributed processing' chapter in the 'General information about system' User Manual).

   2. Click the **Distributed processing** button. Distributed processing tasks are created. Number of created tasks matches with number of LAS-files.

4.3. Data compression

To save free hard disk space, the system provides for compressing LAS-files into archives with the `*.laz` extension. To provide for further work with LAS-files, the system also allows to extract archives with the `*.laz` extension.

To create an archive file with the `*.laz` extension, perform the following:

1. Choose **Terrain › LAS › Convert LAS-files to LAZ...**. The **Convert LAS-files to LAZ** window opens:

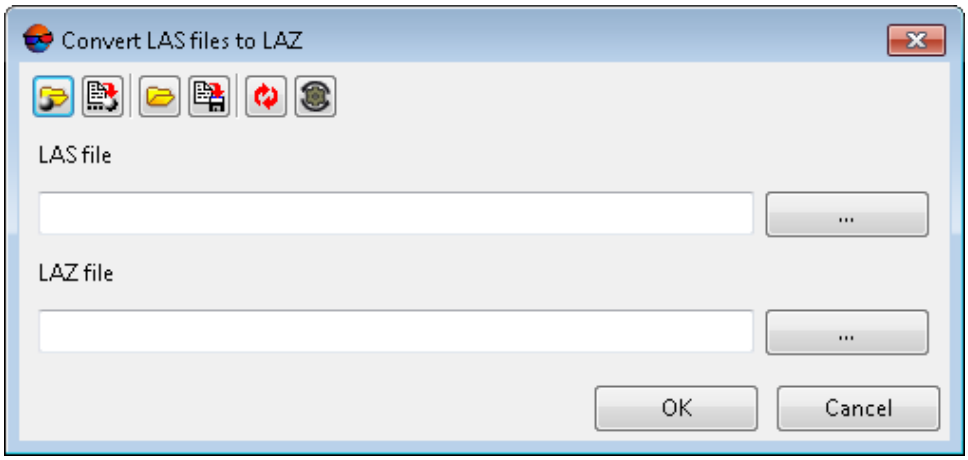

Fig. 16. The “Convert LAS-files to LAZ” window

A toolbar in the upper part of the window is intended to save/load parameter’s settings and contains the following buttons:

- – allows to load parameter’s settings saved previously to active profile resources;
- – allows to save all parameter’s settings to `*.x-ini` file located in active profile resources;
- – allows to load parameter’s settings from *`*.x-ini`* file located in a folder of *Windows* file system;
- – allows to save parameter’s settings to `*.x-ini` file located in a folder of *Windows* file system;
- – allows to restore the last-session’s settings;
- – allows to restore default parameter’s settings.

2. Click the ... button to select initial **LAS file** in the active profile resources;
3. Click the ... button to select output **LAZ file** in the active profile resources;
4. Click OK.

To extract an archive with the `*.laz` extension, perform the following:

1. Choose **Terrain › LAS › Convert LAZ-files to LAS...**. The **Convert LAZ-files to LAS** window opens:

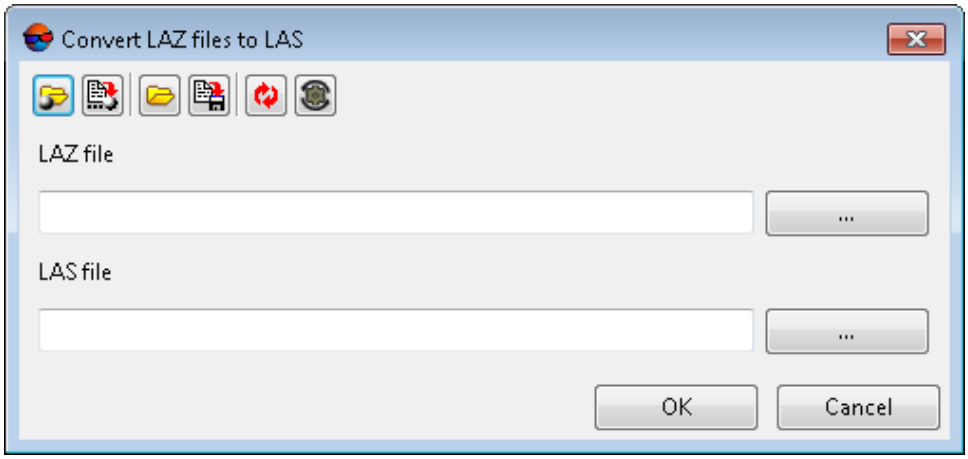

Fig. 17. The “Convert LAZ-files to LAS” window

A toolbar in the upper part of the window is intended to save/load parameter’s settings and contains the following buttons:

- – allows to load parameter’s settings saved previously to active profile resources;
- – allows to save all parameter’s settings to `*.x-ini` file located in active profile resources;
- – allows to load parameter’s settings from *`*.x-ini`* file located in a folder of *Windows* file system;
- – allows to save parameter’s settings to `*.x-ini` file located in a folder of *Windows* file system;
- – allows to restore the last-session’s settings;
- – allows to restore default parameter’s settings.

2. Click the ... button to select initial **LAZ file** in the active profile resources;
3. Click the ... button to select output **LAS file** in the active profile resources;
4. Click OK.

4.4. LAS interpolation

The system allows to change the resolution and size of LAS point cloud fragments (tiles).

To do this, perform the following:

1. Choose **Terrain › LAS › LAS Interpolation...**. The **LAS interpolation** window opens;

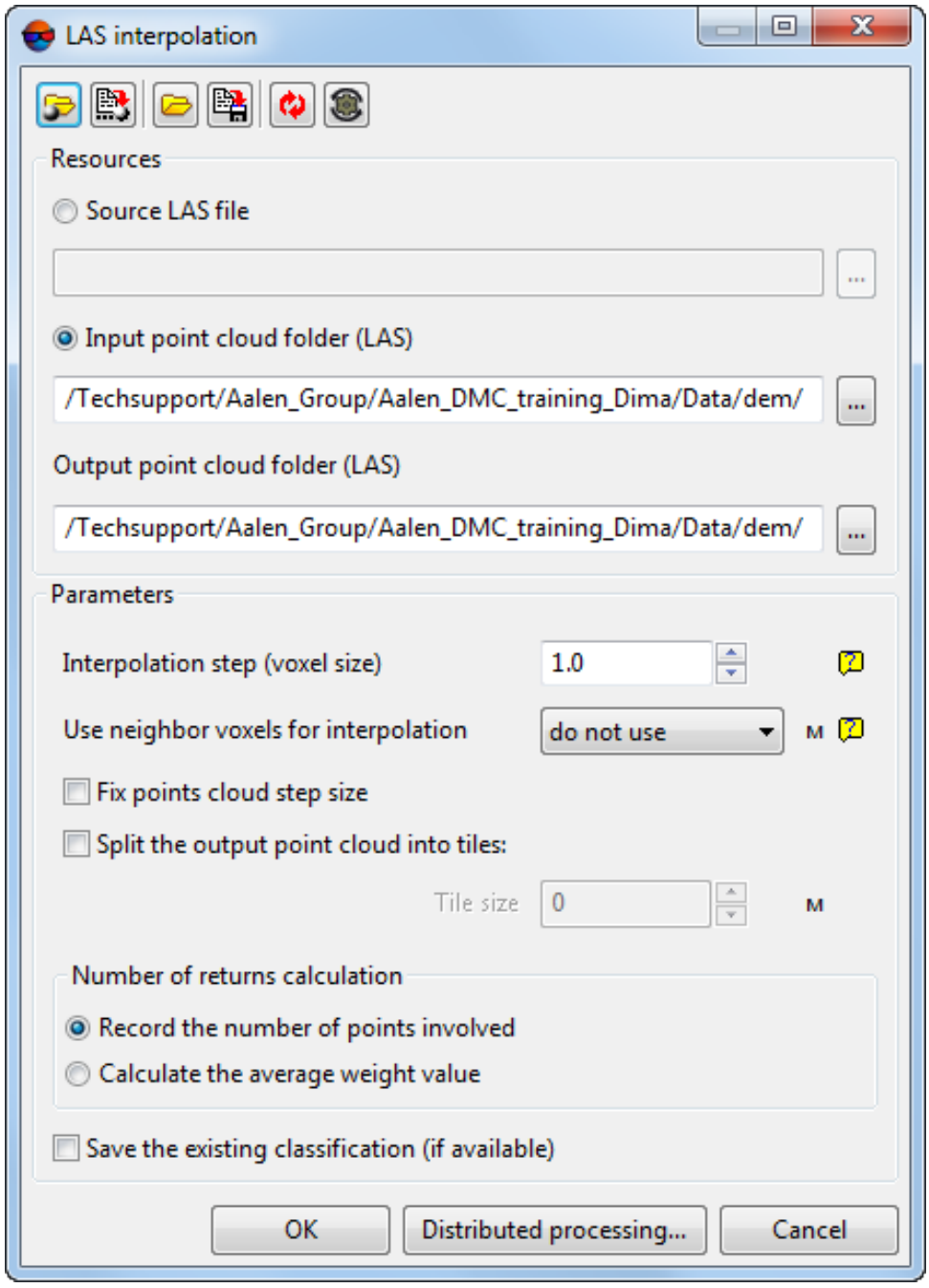

Fig. 18. The “LAS interpolation” window

The **LAS interpolation** window contains the following elements:

- A toolbar in the upper part of the window, which is intended to save/load parameter's settings and contains the following buttons:
  -  – allows to load parameter's settings saved previously to active profile resources;
  -  – allows to save all parameter's settings to `*.x-ini` file located in active profile resources;
  -  – allows to load parameter's settings from *`*.x-ini`* file located in a folder of *Windows* file system;
  -  – allows to save parameter's settings to `*.x-ini` file located in a folder of *Windows* file system;
  -  – allows to restore the last-session's settings;
  -  – allows to restore default parameter's settings.
- The **Resources** and interpolation **Parameters** sections.

2. Select the input **Resources** in an appropriate section:
   - [optional] **Source LAS file** – click the ... button to select input LAS points cloud in active profile resources;

      To process a point cloud saved as a single file.

   - [optional] **Input point cloud folder (LAS)** – click the ... button to select the folder with input point cloud tiles in active profile resources.

      To process a fragmented point cloud.

3. To save LAS files in the **Output LAS files directory** input a path in the appropriate field or click the ... button, to select name and path in active profile resources.
4. Set the following LAS interpolation **parameters** in the appropriate section:
   - **Interpolation step** (a voxel size) – the output cloud point resolution, in the project units;

      A volumetric pixel (*voxel*) is the three-dimensional equivalent of a pixel and the tiniest distinguishable element of a 3D object. Volume pixels are used like building blocks to form a larger 3D object.

In this case, a *voxel* is a small fragment of the input point cloud, within which, during interpolation, one point of the output cloud is calculated. Not to be confused with the tile size.

- **Use neighbor voxels for interpolation** – allows to take into account the content of neighbor voxels (see the figure below) when a current voxel processing:
  - **do not use** – neighbor voxels are not taken into account during the interpolation of a processed voxel content (a voxel is processed separately from others);
  - **use 6 neighbors** – when interpolating the content of the processed voxel of a point cloud, points located in the 6 closest voxels are taken into account;
  - **use 18 neighbors** – when interpolating the content of the processed voxel of a point cloud, points located in the 18 closest voxels are taken into account;
  - **use 26 neighbors** – when interpolating the content of the processed voxel of a point cloud, points located in the 26 closest voxels are taken into account.

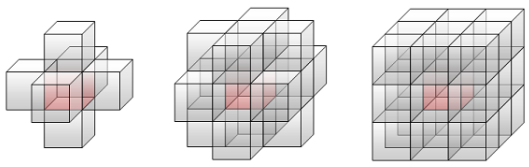

Fig. 19. A processed voxel of a point cloud (red) and the closest neighbor voxels (6, 18 or 26)

- The **Fix points cloud step size** checkbox allows to place each point of an output cloud exactly in the center of the voxel within which this point was calculated. Otherwise – the location of the given point is determined from the interpolation of an input cloud's points within a voxel.
- To **split output point cloud into tiles** set the appropriate checkbox and specify **the tile size** of an output point cloud (XYZ), in the project units;

Use this function carefully. When creating an output point cloud as a single file it is necessary to take into account the size of the output cloud size and the system performance.

Creation of more than 4 – 8 Gb files may negatively affect the system performance and impede viewing and/or further processing the output point cloud.

The size of the output file can be assessed as follows: if the initial point cloud is fragmented, the size of the output LAS as a single file is approximately corresponds to the amount of space on the workstation hard drive, which is the **Input point cloud folder** occupies.

- The **number of returns calculation** section allows to set the algorithm to calculate the number of reflected pulses for the output LAS points:

- **calculate the weight-average value** of the number of reflected pulses for the each point of output LAS, taking into account this parameter value for the processed input cloud points;
- **record the number of points involved** in the processing when calculating the output LAS point.

The system supports the use of LAS files regardless of the way the data was received.

Thus, the system allows to interpolate both lidar data themselves and LAS point clouds created using *PHOTOMOD* (see the "Dense DEM generation using SGM method" section of the "DTM Generation" User Manual).

Hence, the "number of reflected pulses" parameter for the input LAS points may have different meanings, depending on the source of the given point cloud.

In case of the cloud of points, created during the DEM creation using the SGM method, the number of reflected pulses in the given point is the number of stereopairs on the basis of which a particular point was calculated: 1, 2, 3, 4, 5, 6, 7, or 8.

Limitation of the "number of reflected pulses" by 1 to 8 results from the limitations of the LAS format itself, accordingly, in the latter case, the number of stereopairs can be both "8" and "8 and more".

For points of the output LAS point cloud after interpolation, the meaning and values of the "number of reflected pulses" parameter depends on the input data and on whether the **Calculate numbers of returns as weighted average** checkbox was set or cleared.

- To **save the existing classification (if available)** set the appropriate checkbox.

5. Click OK to start LAS interpolation in usual mode.

   In order to interpolate LAS points cloud using distributed processing, do the following:

   1. Change settings and run the distributed processing server/client (see the '*Distributed processing*' chapter in the 'General information about system' User Manual).
   2. Click the **Distributed processing** button.

4.5. Point cloud colorization by project images

The system provides for colorizing a point cloud using project images. This function is available for any point cloud that displays objects within a territory covered by the project images. When coloring, initial points of the LAS file are sequentially projected onto each image of the project.

To do this, perform the following actions:

1. Load the required project;

2. Choose **Terrain › LAS › Colorization by project images**. The **Colorization by project images** window opens;

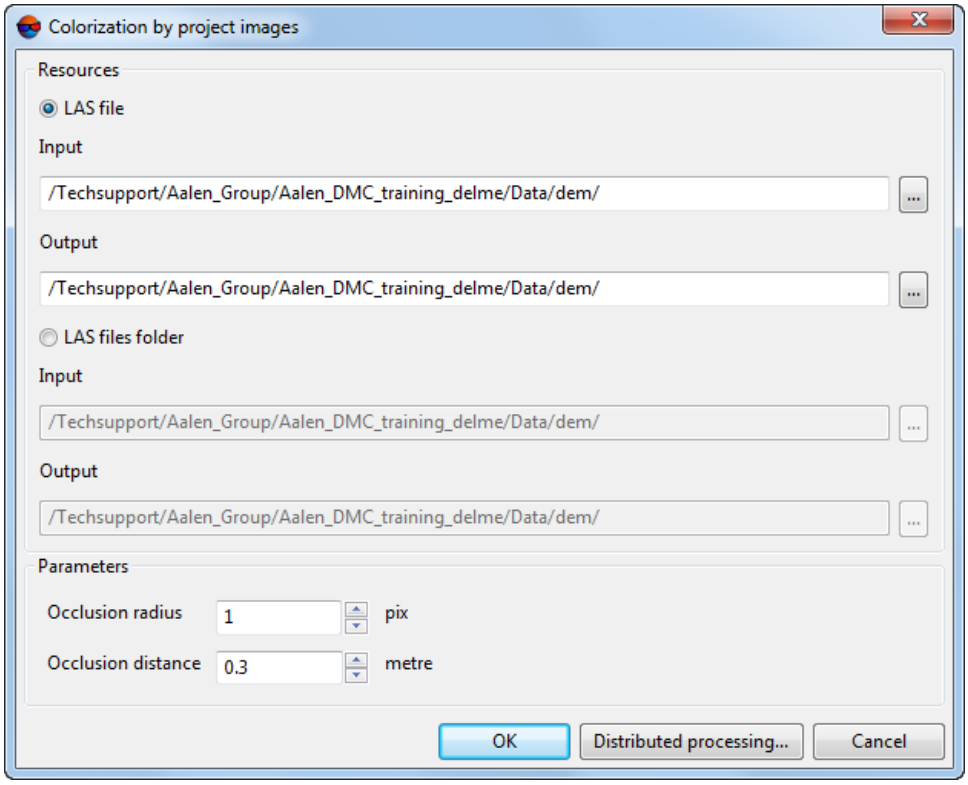

Fig. 20. The “Colorization by project images” window

3. Select the input **Resources**:

   - [optional] **LAS file** – to process a point cloud saved as a single file;
   - [optional] **LAS files folder** – to process a fragmented point cloud.

4. [optional] Click the ... button to select a **Input LAS file** or **Input LAS folder** in active profile resources;

5. [optional] Click the ... button to set an **Output LAS file** location or **Output LAS files folder** in active profile resources;

   Input LAS files folder folder and **Output LAS files folder** must not coincide, otherwise the appropriate message is displayed.

6. Set the overlapping objects colorization **parameters**:

   - Set the **occlusion radius** around the pixel preselected for LAS point coloring (for each image of the project the given point was projected onto), in pixels;

- Set the **Occlusion distance**, in the project units.

If within the **occlusion radius** neighbor pixels are found that are closer to the LAS point, and the difference in distance from pixels to the point exceeds **occlusion distance**, the pixel of the given image will not be involved in final LAS point color determination.

Recommended **Occlusion radius** is several pixels. If this parameter is set to zero, invisible areas will not be checked what may result in incorrect colorization of overlapping objects (especially when processing projects with “oblique” survey data as source data).

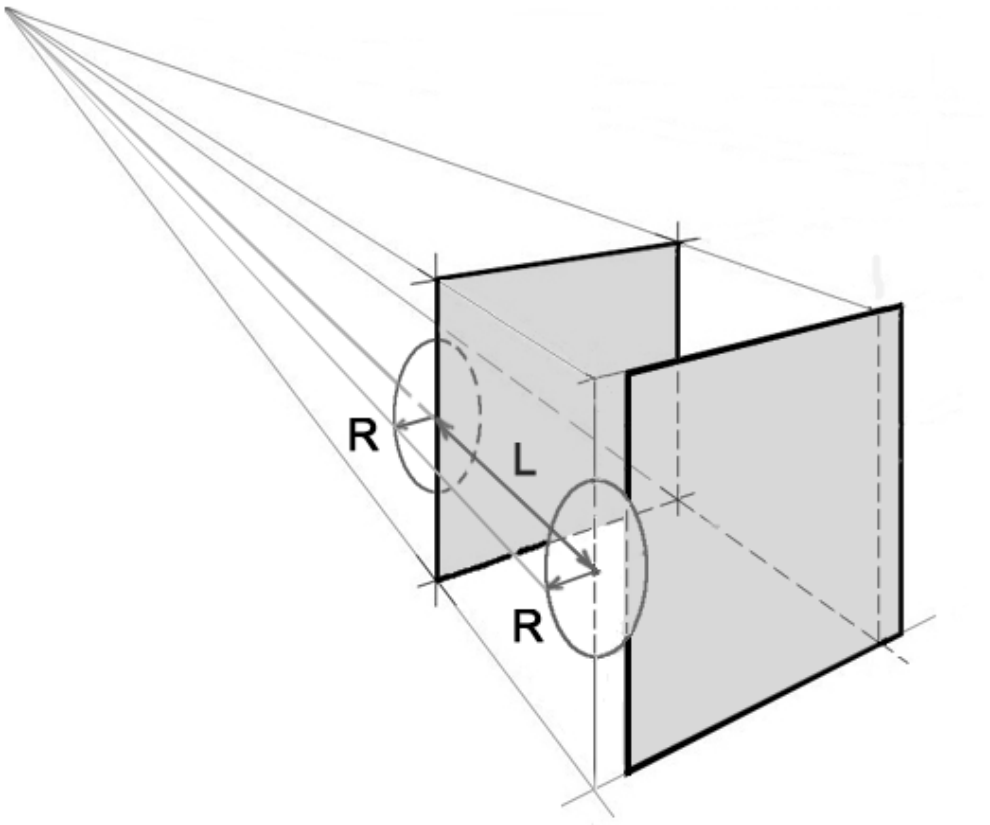

Fig. 21. Invisible areas when texturing overlapping objects (hatched), where R is the **Occlusion radius** and L is the **Occlusion distance**

7. Click OK. As a result, processed LAS files will be created in the output folder having the names identical to the file names in the input folder.

   In order to perform the LAS files colorization using distributed processing, do the following:

1. Change settings and run the distributed processing server/client (see the '*Distributed processing*' chapter in the 'General information about system' User Manual).

2. Click the **Distributed processing** button.

4.6. Lidar point classification

The system provides for attributing classes to lidar points (or changing them). The following lidar point classification procedure is recommended (generally):

- Automatic lidar point classification;
- Viewing and analyzing the results in the **Load LAS** window;

Click the button to enable the coloring mode to accordance with objects classification.

- Manual classification of individual groups of points.

Viewing and manual processing of a point cloud of large size may require the use of significant system resources. The placement of processed files on a SSD drive, as well as the correct dividing of a single point cloud file into separate fragments (tiles) can contribute to an increase in system performance.

4.6.1. Automatic classification by NDVI

The system provides for performing the points classification through the computation of NDVI of processed points.

NDVI is the normalized difference vegetation index. *Vegetation index* is a numerical indicator of the quality and quantity of vegetation in the studied area.

NDVI is one of the most widely used vegetation indices. It is the ratio between the difference in the intensities of reflected light in the red (Red) and near infrared (NIR) bands and their sum:

```
NDVI = (NIR - RED) / (NIR + RED)
```

To calculate the NDVI index, the input lidar data must have an IR channel. The IR band is supported e.g. for some data record formats in v1.4 LAS files (Point Data Record Format 8). Format and version of initial LAS-files depend on data provider. More info see *ASPRS (American Society for Photogrammetry and Remote Sensing)* v1.4 LAS specifications.

The system also provides for classification in project images using the NDVI index (if the source images have an IR channel). To do this, create a point cloud using the functionality of the *PHOTOMOD* software first (see the "Dense DEM generation using SGM method" chapter of "DTM Generation" User Manual).

To create a point cloud during dense DEM creation using the SGM method, set the **Create** checkbox in the **Point cloud (LAS)** section of the **SGM parameters** window. To record IR-band

data into the LAS file under creation, click **Parameters** button in the **Point cloud (LAS)** section and set the **Classify vegetation by IR channel (if available)** checkbox in the **LAS creation parameters** window.

The point cloud created in this way by tools of *PHOTOMOD* software (if the source images have an IR channel) contains the necessary data to perform the classification described below.

The value of the **point class** parameter initially depends on the data provider (the point may be not classified), and later on - on the subsequent processing that the point cloud is subjected to.

The system also provides for the classification of a DEM according to NDVI, that is carried out in a similar way (see “DEM classification” in the “DTM Generation” User Manual).

To classify vegetation in the territory described by the point cloud, perform the following:

1. Select **Terrain › LAS › Classification by NDVI**. The **Classification by NDVI** window opens.

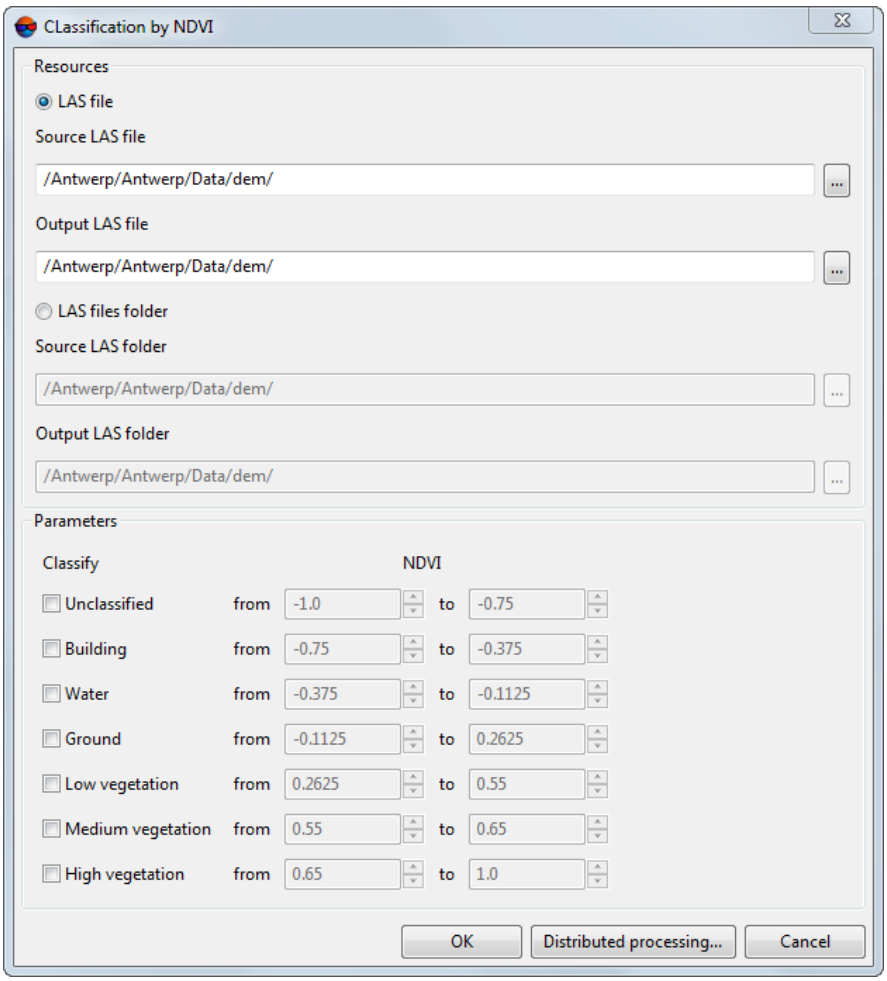

Fig. 22. The “Classification by NDVI” window

2. Select input **resources** to use:

   - [optional] **LAS file** – to process a point cloud stored as a single file;
   - [optional] **LAS files folder** – to process a point cloud split into fragments.

3. Click ... to select a **Source LAS file** in the active profile resources. **Source LAS folder** is selected in the same way;

4. In the **Output LAS file** field, enter the path for saving output data, or click ..., to specify the path in the active profile resources. A folder in the active profile resources where output LAS files will be located is specified by the same way;

   

   The folders with input and output LAS files must not be the same, in this case an appropriate message is issued.

5. Set the **parameters** for classification. To assign one of expected classes to points, set the appropriate checkbox, and edit the default range of NDVI values, if needed.

   

   Common NDVI value limits are from -1 to 1. Values from -1 to 0 are reserved for infrastructure objects, as well as for non-wildlife objects (e.g. snow, water, sand, stones, houses, roads, etc.). Values for vegetation are between 0 and 1.

   

   Ranges of NDVI-index values whereby points will be classified, should not overlap each other (since more than one value of the Class parameter cannot be assigned to a point).

   Before starting the operation, an appropriate check is performed. In case of overlapping between NDVI ranges, an appropriate message is issued.

6. Click OK. To perform classification through the distributed processing, perform the following:

   1. Configure and start the server/client of distributed processing (see “Distributed processing” in the “General information” User Manual).
   2. Click the **Distributed processing** button.

7. After the successful completion of the operation, an appropriate message is displayed. The processed LAS files are created in the output folder. The points of the processed files have the values of the **Point class** parameter filled in (see the LIDAR data loading and displaying chapter).

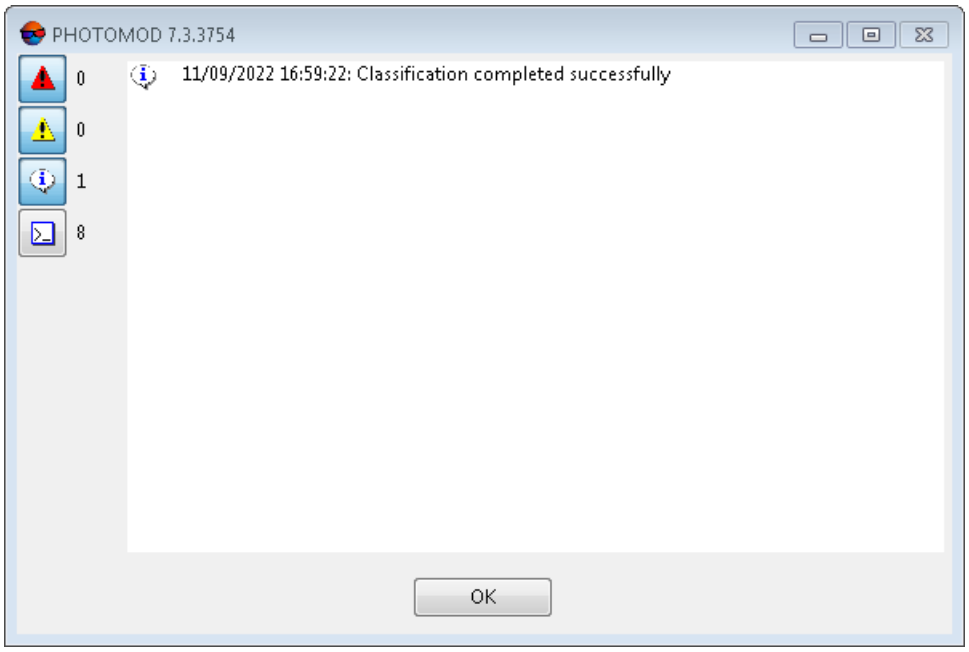

Fig. 23. The info message

4.6.2. Manual point groups classification

The system provides for group attributing the following **point classes** to lidar points:

- **Ground**;
- **Low vegetation**;
- **High vegetation**;
- **Building**;
- **Water**;
- **Road**.

Data on the **point classes** are recorded in a LAS file after the user clicks the appropriate **Load LAS** toolbar button (without requiring additional confirmation from the user).

It is impossible to undo this operation (the user only has the opportunity to edit the selected group of points later again in the same way). It is recommended to back up the relevant files (resources) before manual classification.

To assign manually **point class** attributes to selected groups of lidar points, perform the following:

1. Open the **Load LAS** window;

2. Open the LAS file located in the *Windows* file system or in the active profile resources;

   The LAS file under processing which is located in the *Windows* file system is to be recordable (for example, not open in other running *PHOTOMOD* modules or in other programs).

   Click the button to enable the coloring mode to accordance with objects classification.

3. Select the desired lidar points groups;

4. To assign one of available **point classes** to the selected point groups, click the appropriate button in the **Load LAS** window toolbar intended for manual lidar point classification:

Table 7. Toolbar allowing to classify LIDAR data

Buttons	Functions
	allows assign the **high vegetation** standard class to manually selected ( ) lidar points (5)
	allows assign the **low vegetation** standard class to manually selected lidar points (3)
	allows assign the **road surface** standard class to manually selected lidar points (11)
	allows assign the **ground** standard class to manually selected lidar points (2)
	allows assign the **building** standard class to manually selected lidar points (6)
	allows assign the **water** standard class to manually selected lidar points (9)
	allows assign the **transport** class to manually selected lidar points. This class is used in *PHOTOMOD* and is not a part of the *ASPRS*-developed standard classification (this software uses one of the “reserved” classes, considering it as transport, inside the *PHOTOMOD* system).
None	allows assign the **Created, never classified** standard class to manually selected lidar points (0)

5. After the classification is complete, click in the **Load LAS** window toolbar to disable the lidar point group selection mode.

4.7. Building a histogram by a point cloud

The system provides for building a histogram by a point cloud, according to lidar point classification.

An available classified points are essential for building a LAS file histogram.

The value of the **point class** parameter initially depends on data provider (the point may be not classified), and later on – on the subsequent processing that the point cloud was subjected to (for example, lidar point classification according to the NDVI index, using the *PHOTOMOD* software tools, performed with user settings).

Thereof, in the latter case (depending on the settings specified by the user during the latest classification) the mutual ratio of the current **point class** and the calculated NDVI index may not comply with common standards.

Note, that point class is the property of a lidar point that can be recorded in a LAS file (optionally, if such data is available), while the NDVI index is calculated by the system when accessing a particular point.

NDVI is the ratio between the difference in the intensities of reflected light in the red (Red) and near infrared (NIR) bands and their sum:

```
NDVI = (NIR - RED) / (NIR + RED)
```

To build a histogram, perform the following:

1. Select **Terrain › LAS › Load LAS...** to open the **Load LAS** window;
2. Click or in the **Load LAS** toolbar to open a lidar data file. Select one or more LAS files.

   An integrated histogram will be built for all point clouds displayed in the workspace in the right part of the **Load LAS** window.

   If user build a histogram for several point clouds at once, for the correct display of information it is strongly recommended to use clouds classified with the same user settings as input data.

   To display any given point cloud in the workspace in the right part of the **Load LAS** window, set the appropriate checkbox in the list of loaded LAS files.

3. Click the toolbar button. Wait until the histogram is built. The **Histogram** window opens:

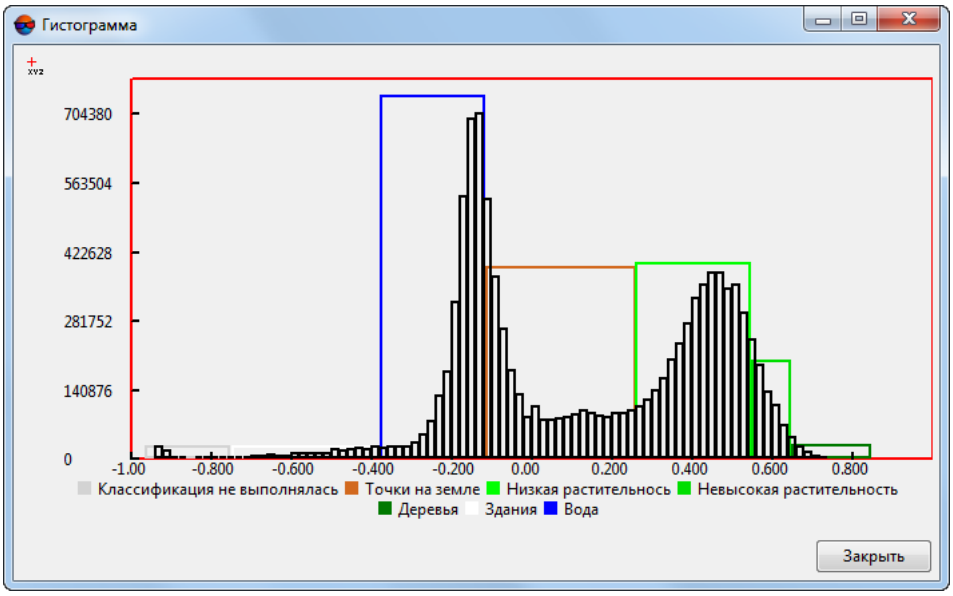

Fig. 24. The “Histogram” window

The histogram displays the distribution of the number of lidar points (Y-axis) within the range of possible NDVI-index values: from -1 to 1.

Common NDVI values are: from -1 to 1. Values from -1 to 0 are reserved for infrastructure objects, as well as for non-wildlife objects (e.g. snow, water, sand, stones, houses, roads, etc.). Values for vegetation are between 0 and 1.

Actual (inherent to a particular point cloud) ranges of NDVI values are displayed in the **Histogram** window as colored rectangles. An information block that correlates a specific range of NDVI values with one of the point classes is located in the lower part of the window.

To display a tooltip with the exact values of the number of cells (**Y**-axis) and the range of NDVI values (**X**-axis) when you hover over an individual diagram column, click button.

To disable the tooltip mode, click the button.

5. LAS filtering

5.1. LAS filtering by elevations and numbers of reflected pulses

The system provides possibility to filter lidar data and point clouds (obtained as a result of DEM creation using the SGM method), by elevations and numbers of reflected pulses in each point, to remove accident surges.

When filtering accident surges, the system provides possibility to use the reference surface of DEM (created together with the LAS cloud of points, or covering the same territory – see the “Dense DEM generation using SGM method” chapter of the “DTM Generation” User Manual).

In order to filter LIDAR data perform the following actions:

1. Choose **Terrain › LAS › Filter LAS...**. The **LAS filtering** window opens;

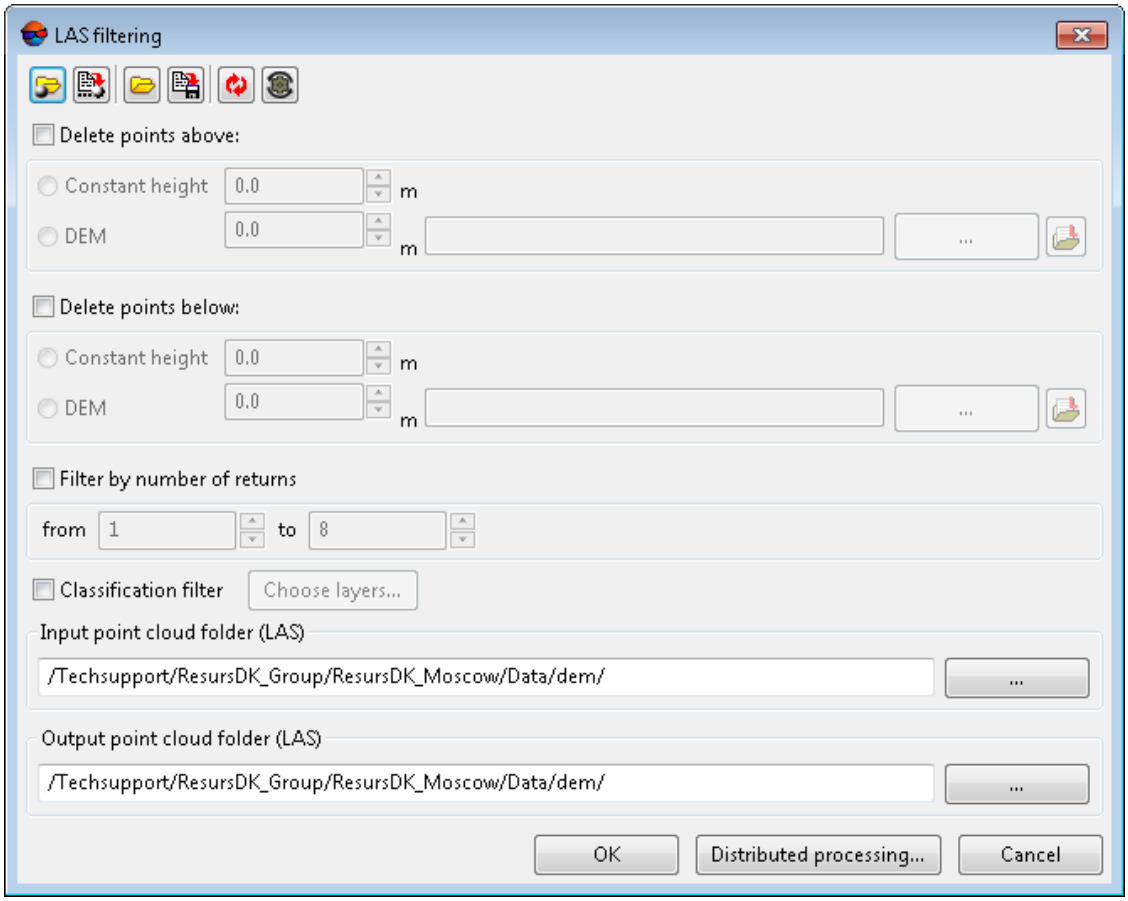

Fig. 25. The “LAS filtering” window

A toolbar in the upper part of the window is intended to save/load parameter’s settings and contains the following buttons:

- – allows to load parameter’s settings saved previously to active profile resources;
- – allows to save all parameter’s settings to `*.x-ini` file located in active profile resources;
- – allows to load parameter’s settings from *`*.x-ini`* file located in a folder of *Windows* file system;

- – allows to save parameter's settings to `*.x-ini` file located in a folder of *Windows* file system;
- – allows to restore the last-session's settings;
- – allows to restore default parameter's settings.

2. Click the ... button in the **Input point cloud folder (LAS)** field and select the folder with lidar data or point cloud in active profile resources;

   The filtering process will be started for every LAS file in the selected folder (e.g. for the point cloud, divided into tiles).

3. Click the ... button in the **Output point cloud folder (LAS)** field and select a folder for output data in active profile resources;

   Source folder and **Destination folder** must not coincide, otherwise the appropriate message is displayed.

4. [optional] set the **Delete points above** checkbox and adjust LAS filtering settings by the elevation:

   - **Constant height** – set the height in meters (all points above the preselected height will be removed);
   - **DEM** – click the ... button to select DEM as a reference surface in the active profile resources. Enter the value of permissible elevation above the DEM surface, in meters (all points above the DEM surface will be removed, except for those not exceeding the given permissible elevation).

     Click the button to open the **Layer selection** window and select the source DEM from the list of DEMs uploaded to the project.

     Too low or zero values of the permissible elevation may cause removal of "good" points, and hence, "sparse" point cloud.

     Recommended value is no less than RMS by Z in stereopairs (see the "Brief residuals report" chapter of the "Block adjustment" User Manual).

5. [optional] set the **Delete points below** checkbox and adjust LAS filtering settings by the elevation:

   - **Constant height** – set the height in meters (all points below the preselected height will be removed);
   - **DEM** – click the ... button to select DEM as a reference surface in the active profile resources. Enter the value of permissible deviation from the DEM surface,

in meters (all points below the DEM surface will be removed, except for those not exceeding the given permissible deviation).

Click the button to open the **Layer selection** window and select the source DEM from the list of DEMs uploaded to the project.

For correct filter operation, *in case of filtering points below the DEM surface*, the reference DEM should be the digital terrain model, i.e. *do not include data on buildings and vegetation*.

To create such a reference DEM, it is recommended to use *Buildings and vegetation filter* or *Slope based filter* (see the “DEM filtering” chapter of the “DTM Generation” User Manual).

Recommended permissible deviation value is no less than RMS by Z in stereopairs (see the “Brief residuals report” chapter of the “Block adjustment” User Manual).

6. [optional] set the **Filter by number of returns** checkbox to adjust LAS filtering settings according to the number of reflected pulses in every point (in case of available data of such type in the LAS format file);

When filtering the cloud of points, created during the DEM creation using the SGM method, this parameter has somewhat different meaning.

In this case, in the LAS file, the number of reflected pulses in the given point is the number of stereopairs on the basis of which a particular point was calculated: 1, 2, 3, 4, 5, 6, 7, or 8.

Limitation of the “number of reflected pulses” by 1 to 8 results from the limitations of the LAS format itself, accordingly, in the latter case, the number of stereopairs can be both “8” and “8 and more”.

It is recommended to filter points calculated on the base of two and less stereopairs. Too strict filtering settings in relation to used stereopair numbers can result in removing “good” points, and hence “sparse” cloud of points (and therefore it may not to display some objects).

7. [optional] set the **Classification filter** checkbox to set LAS filtering parameters according to the classification of points (see the LAS specification published by *ASPRS* and Appendix A);

Click **Choose layers**. The **LAS classification filter parameters** window opens:

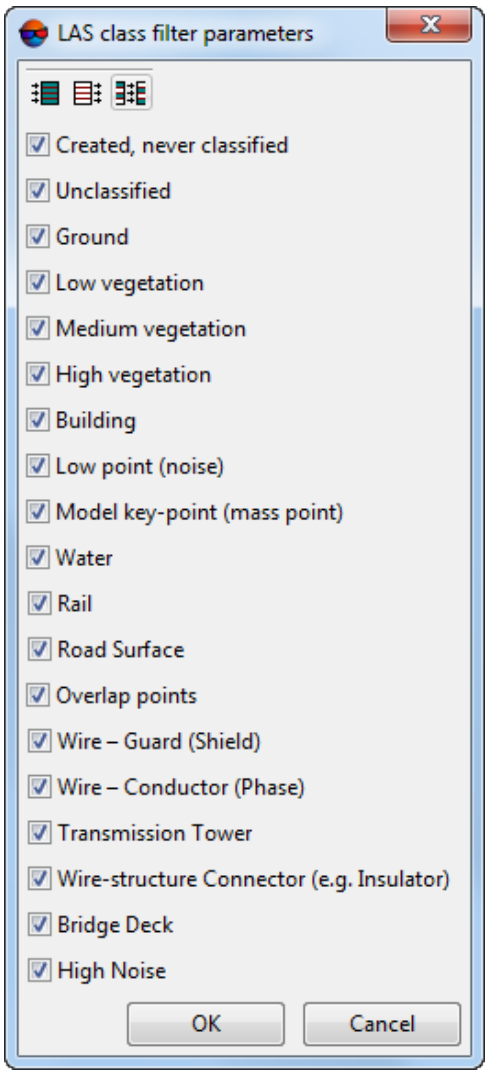

Fig. 26. The “LAS classification filter parameters” window

To remove LAS points ranked in a certain way from the resulting file, clear the appropriate checkboxes. For group selection of point types, the following buttons are provided in the **LAS classification filter parameters** window:

- – allows you to select types of lidar points;
- – allows you to deselect all types of lidar points;
- – allows you to invert selection of point types;

8. Click OK. As a result, processed LAS files will be created in the **Destination folder** having the names identical to the file names in the Initial folder.

5.2. LAS smooth filter

The system allows for point cloud filtering to eliminate noise.

In order to filter LIDAR data perform the following actions:

1. Choose **Terrain › LAS › LAS smooth filter**. The **LAS filtering** window opens;

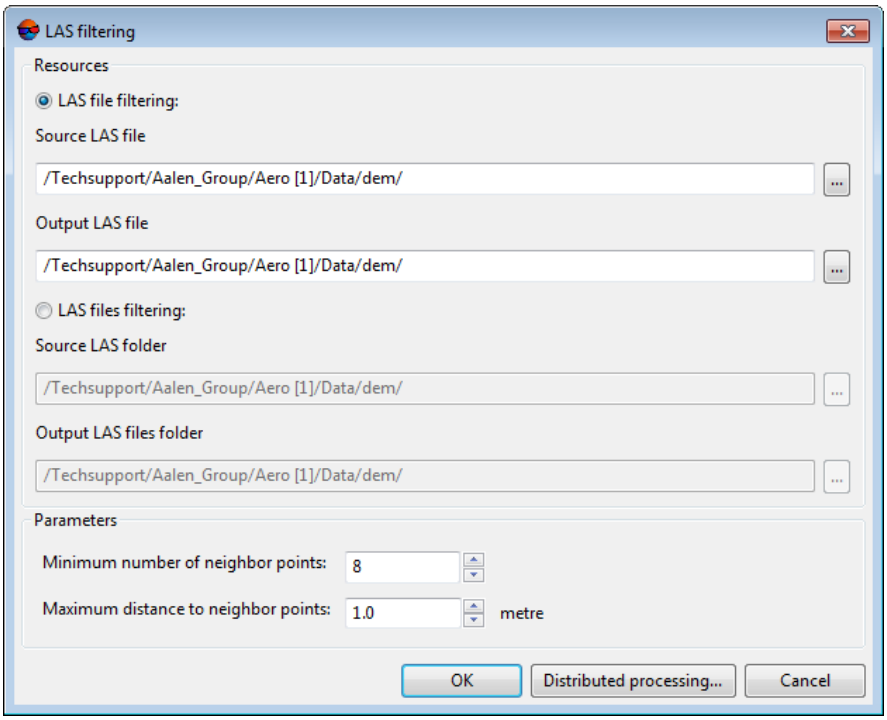

Fig. 27. The “LAS filtering” window

2. Select the input **Resources**:
   - [optional] **LAS file filtering** – to process a point cloud saved as a single file;
   - [optional] **LAS files filtering** – to process a fragmented point cloud.
3. [optional] Click the ... button to select a **Source LAS file** or **Source LAS folder** in active profile resources;
4. [optional] Click the ... button to set an **Output LAS file** location or **Output LAS files folder** in active profile resources;

   Source LAS folder folder and **Output LAS files folder** must not coincide, otherwise the appropriate message is displayed.

5. Set the following filtering **parameters**:

- **Maximum distance to neighbor points** (in the projects units) – a search radius for neighbor points;
- **Minimum number of neighbor points** – the least number of neighbor points. When not enough, a point is removed.

Recommended **Minimum neighborhood points count** is about 6 or 8 (set by default).

6. Click OK. As a result, processed LAS files will be created in the **Destination folder** having the names identical to the file names in the Initial folder.

   In order to filter LAS using distributed processing, do the following:

   1. Change settings and run the distributed processing server/client (see the '*Distributed processing*' chapter in the 'General information about system' User Manual).
   2. Click the **Distributed processing** button.

5.3. LAS bilateral filter

The system allows for smoothing point cloud filtering to remove "noise" errors taking into account points color (if such data are available in the LAS file).

In order to filter LIDAR data perform the following actions:

1. Choose **Terrain › LAS › LAS bilateral filter**. The **Bilateral filter LAS** window opens;

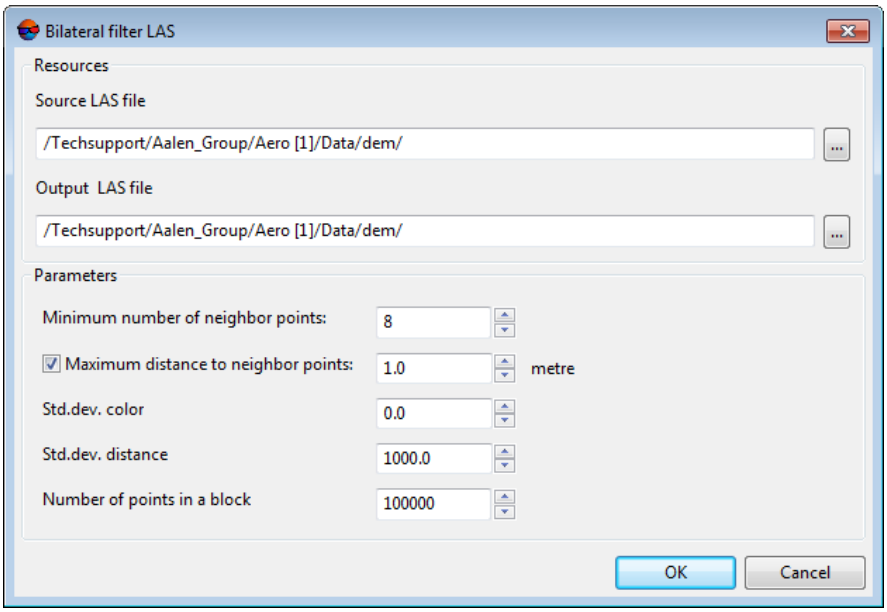

Fig. 28. The “Bilateral filter LAS” window

2. In **resources** section click an appropriate ... buttons to select a **Source LAS file** and set an **Output LAS file** location;

3. Set the following filtering **parameters**:

   - **Minimum number of neighbor points** involved into computations for the given point;
   - [optional] To limit **Maximum distance to neighbor points**, set the appropriate checkbox and set the neighbor point search radius, in the project’s units;
   - **Std. dev. color**, allows to limit weight influence of neighbor points, depending on their color characteristics;

     With the minimum standard deviation, the filtering process will take into account the influence of only the closest in color neighboring points. At the limit values of the standard deviation, all points with the maximum weight will be taken into account, regardless of their color.

   - **Std. dev. distance**, allows to limit the weigh influence of neighbor points, depending on their distance to the point for which the calculations are made;
   - A **Number of points in a block** allows to divide a large point cloud into sequentially processed fragments (blocks).

     The recommended approximate size of a processed block for workstations with RAM no less than 16 Gb is about 2 million points.

4. Click OK. As a result, processed LAS files will be created in the **Destination folder** having the names identical to the file names in the Initial folder.

5.4. LAS statistical outlier removal

The system allows to filter rough errors, i.e. single points beyond the main cloud at some distance from it, that are very likely erroneous data.

In order to filter LIDAR data perform the following actions:

1. Choose **Terrain › LAS › LAS statistical outlier removal**. The **LAS statistical outlier removal filter** window opens;

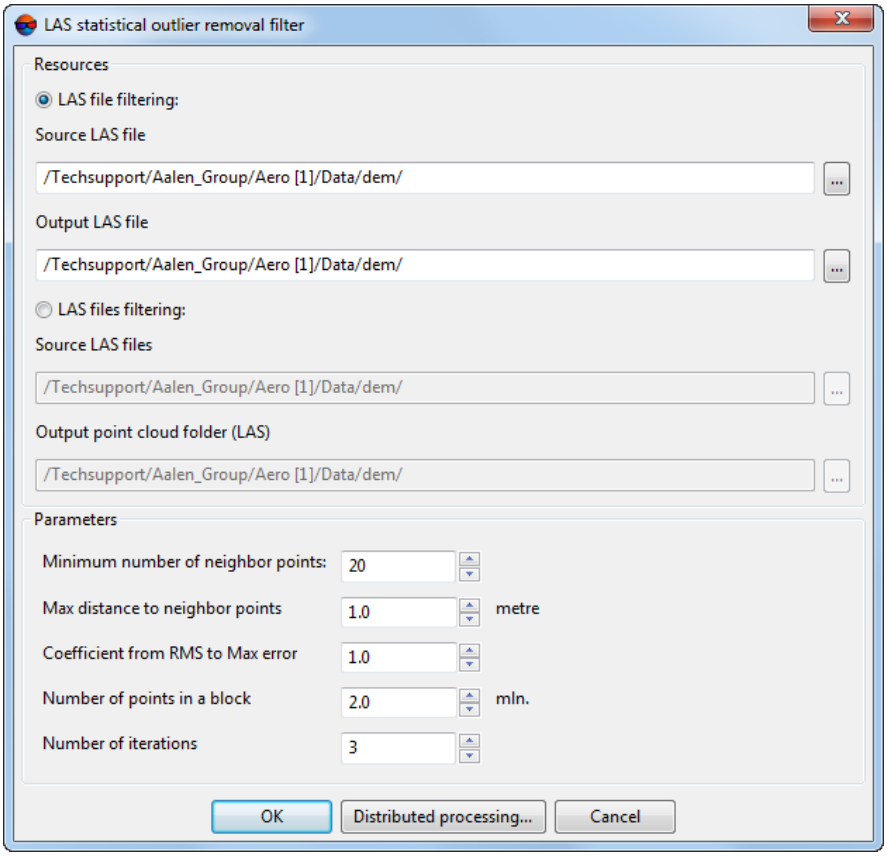

Fig. 29. The “LAS statistical outlier removal filter” window

2. Select the input **Resources**:

   - [optional] **LAS file filtering** – to process a point cloud saved as a single file;
   - [optional] **LAS files filtering** – to process a fragmented point cloud.

3. [optional] Click the ... button to select a **Source LAS file** or **Source LAS folder** in active profile resources;

4. [optional] Click the ... button to set an **Output LAS file** location or **Output LAS files folder** in active profile resources;

   Source LAS folder folder and **Output LAS files folder** must not coincide, otherwise the appropriate message is displayed.

5. Set the following filtering **parameters**:

   - **Minimum number of neighbor points** is the number of neighbor points for the given point not to be deleted;

     Recommended **minimum number of neighbor points** is about 6-8 (default).

   - **Max distance to neighbor points** allows to set the range where the search for neighbor points will be made (in the project's units);

   - **Coefficient from RMS to Max error** – affects further filtering of points having sufficient **minimum number of neighbor points**;

     The **Coefficient from RMS to Max error** is used when calculating the tolerance for the average distance between points in a cloud. The increase of this parameter causes the increased tolerance. The decrease of this parameter's value leads to stricter point filtering.

     This tolerance is calculated as follows:

     - The product of the standard deviation of the distance between points (over the entire cloud) and the Coefficient from RMS to Max error is calculated;
     - This product is added to the average distance between points in the cloud.

   - **Number of points in a block** allows to divide a large point cloud into fragments (block) processed sequentially.

     The recommended approximate size of a processed block for workstations with RAM no less than 16 Gb is about 2 million points.

   - **Number of iterations**.

6. Click OK. As a result, processed LAS files will be created in the **Destination folder** having the names identical to the file names in the Initial folder.

   In order to filter LAS using distributed processing, do the following:

1. Change settings and run the distributed processing server/client (see the '*Distributed processing*' chapter in the 'General information about system' User Manual).

2. Click the **Distributed processing** button.

5.5. LAS fusion

The system allows for point cloud filtering to remove noise taking into account averaged normals from processed points to projection centers of images used in their calculation (if such data are available in a LAS file, see "Dense DEM generation using SGM method" in the "DTM Generation" User Manual).

Filtering is carried out by averaging adjacent points in order to find the optimal surface. Points are filtered within the constructed cylinder, with user-specified parameters. The axis of this cylinder is the averaged normal from the point being processed.

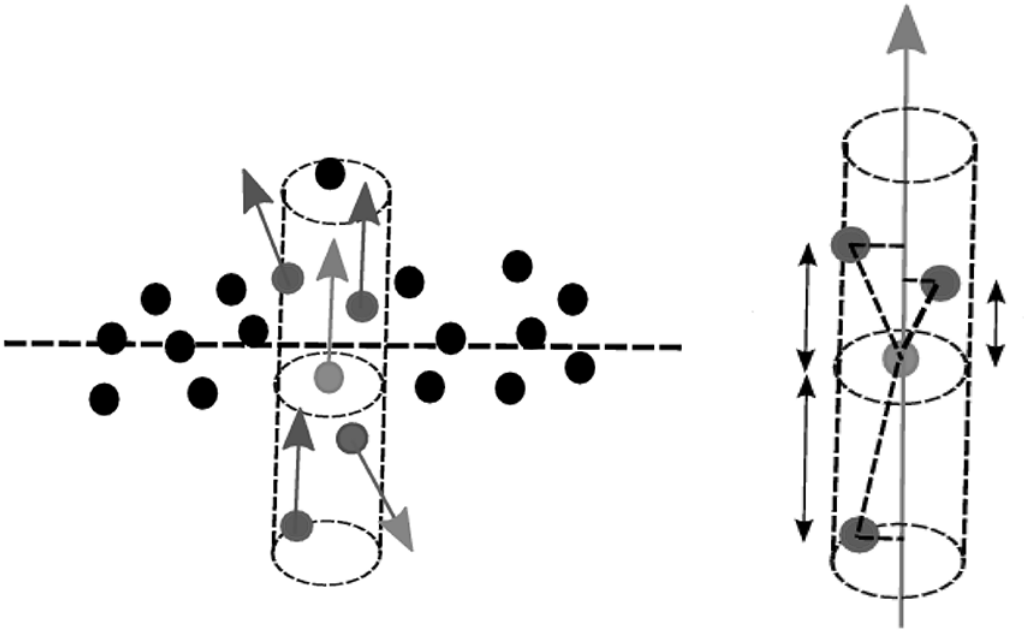

Fig. 30. Filter working principle

In order to filter LIDAR data perform the following actions:

1. Choose **Terrain › LAS › LAS fusion**. The **LAS fusion filter** window opens;

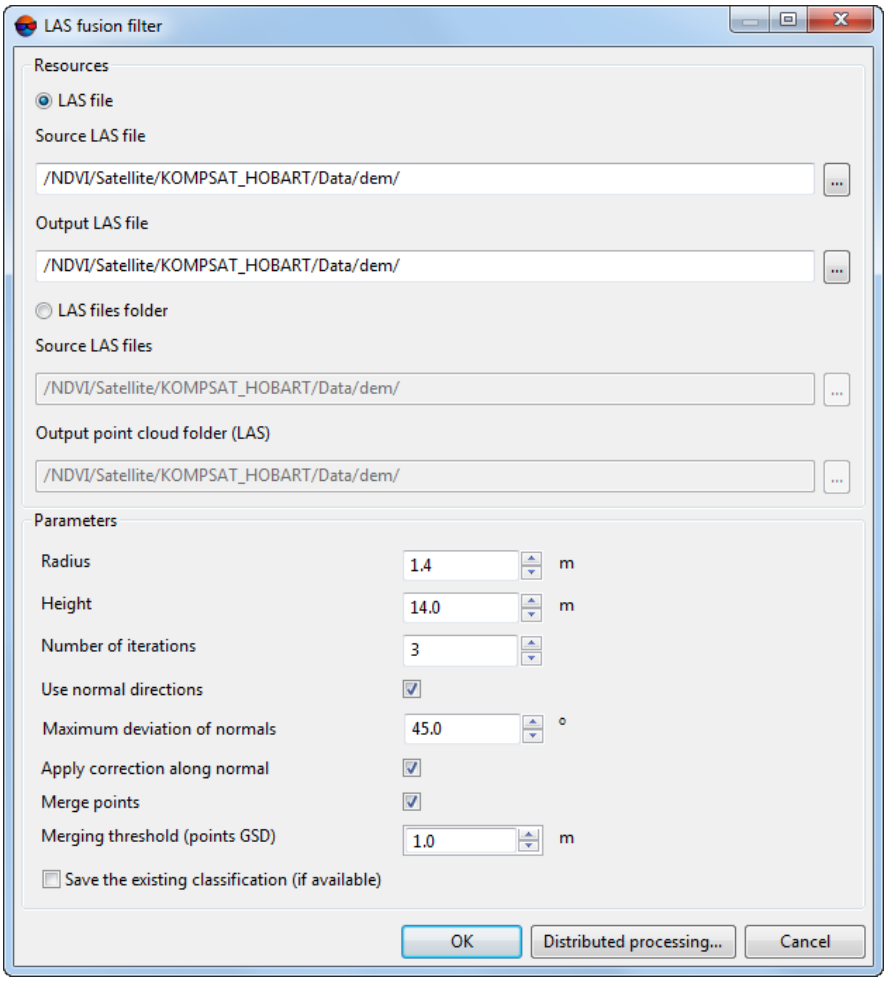

Fig. 31. The “LAS filtering” window

2. Select the input **Resources**:

   - [optional] **LAS file filtering** – to process a point cloud saved as a single file;
   - [optional] **LAS files filtering** – to process a fragmented point cloud.

3. [optional] Click the ... button to select a **Source LAS file** or **Source LAS folder** in active profile resources;

4. [optional] Click the ... button to set an **Output LAS file** location or **Output LAS files folder** in active profile resources;

   Source LAS folder folder and **Output LAS files folder** must not coincide, otherwise the appropriate message is displayed.

5. Set the filtering **parameters**:

- Cylinder's **radius**;
- Cylinder's **height**;
- **Number of iterations**;
- To account for directions of point normals, set the **use normal directions** checkbox. In this case, with each subsequent iteration, the direction of the processed point normal is corrected according to the changes made by the filter, otherwise it remains unchanged relative to its original position;
- Set the **maximum deviation of normals**. Points that fall into the processing area are excluded from the calculations if the deviation of their normals from the cylinder axis exceeds the specified value;
- To calculate the correction along the normal, set the **Apply correction along normal** checkbox. In this case, at each subsequent iteration, the position of the processed point relative to the cylinder's axis is corrected according to the changes made by the filter, otherwise the point is not shifted relative to the cylinder's axis;
- To **merge points** set the appropriate checkbox;
  - Specify the **merging threshold** (set the output points cloud GSD).
- To **save the existing classification (if available)** set the appropriate checkbox.

6. Click OK. As a result, processed LAS files will be created in the **Destination folder** having the names identical to the file names in the Initial folder.

   In order to filter LAS using distributed processing, do the following:

   1. Change settings and run the distributed processing server/client (see the '*Distributed processing*' chapter in the 'General information about system' User Manual).
   2. Click the **Distributed processing** button.

5.6. Manual deleting point groups

To delete some lidar points, select the required point groups, press **Delete** and confirm this operation in the appropriate dialog box by clicking **Yes**:

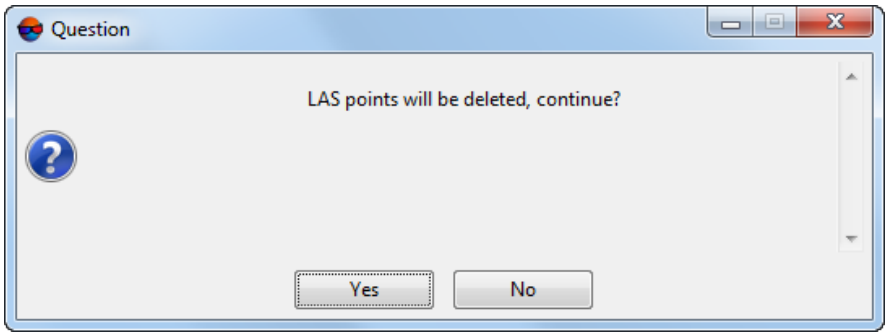

Fig. 32. A dialog box to confirm deletion of lidar points

The relevant LAS-file (or LAS-files, if the point cloud was divided into tiles and the deletion operation affected points in several tiles at once) is overwritten when the user clicks **Yes**. It is impossible to undo this operation. Before making changes to the original files or resources, the system automatically creates their backup copies located in the backup folder, which is automatically created in the same folder as the edited point cloud (in the *Windows* file system or in the active profile resources).

A name of the backup copy is created according the following pattern: `<original file name>.<data yyyy-mm-dd>.<time hh-mm-ss>.las`, for example, `Block_1_1_0.2023-08-29.17-09-02.las`. If necessary, data restoration from backups is carried out manually by the user.

To set the number of backup copies to be created, choose **Service › Settings** or click in the main toolbar. In the **Settings** window that opens, in the **Backups** tab, set the **Number of stored backup copies (per resource) for vector data / point clouds**. If the specified number of backups is exceeded, earlier copies are deleted.

Appendix A. ASPRS Standard Point Classes

Table A.1. Objects classification contained in reflection points attributes according to specification published by ASPRS (LAS v.1.4, point data record formats 6-10)

Classification Value	Meaning
0	Created, never classified (None)
1	Unclassified
2	Ground ( )
3	Low Vegetation ( )
4	Medium Vegetation
5	High Vegetation ( )
6	Building ( )
7	Low Point (noise)
8	*Reserved*
9	Water ( )

Classification Value	Meaning
10	Rail
11	Road Surface ()
12	*Reserved*
13	Wire – Guard (Shield)
14	Wire – Conductor (Phase)
15	Transmission Tower
16	Wire-structure Connector (e.g. Insulator)
17	Bridge Deck
18	High Noise
19	Overhead Structure (e.g., conveyors, mining equipment, traffic lights)
20	Ignored Ground (e.g., breakline proximity)
21	Snow
22	Temporal Exclusion (Features excluded due to changes over time between data sources – e.g., water levels, landslides, permafrost)
23-63	*Reserved*
64-255	User Definable

Created, never classified (0), **Ground** (2), **Low vegetation** (3), **High vegetation** (5), **Building** (6), **Water** (9) and **Road surface** (11) classes can be assigned to point groups during manual classification.

The **transport** class () is used in *PHOTOMOD* and is not a part of the *ASPRS*-developed standard classification (this software uses one of the “reserved” classes, considering it as transport, inside the *PHOTOMOD* system).

Classes assigned to DEM cells are automatically considered during DEM conversion in a LAS point cloud (see “DEM classification” and “Convert DEM to point cloud (LAS)” in the “DTM Generation” User Manual).